TITLE OF THE INVENTION

17 BETA-ACETAMIDE-4-AZASTEROIDS AS ANDROGEN RECEPTOR MODULATORS

FIELD OF THE INVENTION

The present invention relates to 17β-acetamide-4-azasteroid derivatives, their synthesis, and their use as androgen receptor modulators. More particularly, the compounds of the present invention are tissue-selective androgen receptor modulators (SARMs) and are thereby useful for the treatment of conditions caused by androgen deficiency or which can be ameliorated by androgen administration, such as osteoporosis, periodontal disease, bone fracture, frailty, and sarcopenia. Additionally, the SARMs of the present invention can be used to treat mental disorders associated with low testosterone, such as depression, sexual dysfunction, and cognitive decline. SARMs, being antagonists in specific tissues, are also useful in conditions where elevated androgen tone or activity causes symptoms, such as benign prostate hyperplasia and sleep apnea.

BACKGROUND OF THE INVENTION

The androgen receptor (AR) belongs to the superfamily of steroid/thyroid hormone nuclear receptors, whose other members include the estrogen receptor, the progesterone receptor, the glucocorticoid receptor, and the mineralocorticoid receptor. The AR is expressed in numerous tissues of the body and is the receptor through which the physiological as well as the pathophysiological effects of androgens, such as testosterone (T) and dihydrotestosterone (DHT), are mediated. Structurally, the AR is composed of three functional domains: the ligand binding domain (LBD), the DNA-binding domain, and amino-terminal domain. A compound that binds to the AR and mimics the effects of an endogenous AR ligand is referred to as an AR agonist, whereas a compound that inhibits the effects of an endogenous AR ligand is termed an AR antagonist.

Androgen ligand binding to the AR induces a ligand/receptor complex, which, after translocation into the nucleus of the cell, binds to regulatory DNA sequences (referred to as androgen response elements) within the promoter or enhancer regions of the target genes present in the nucleus. Other proteins termed cofactors are next recruited, which bind to the receptor leading to gene transcription.

Androgen therapy has been to treat a variety of male disorders such as reproductive disorders and primary or secondary male hypogonadism. Moreover, a number of natural or synthetic AR agonists have been investigated for the treatment of musculoskeletal disorders, such as bone disease, hematopoietic disorders, neuromuscular disease, rheumatological disease, wasting disease, and for hormone replacement therapy (HRT), such as female androgen deficiency. In addition, AR antagonists,

such as flutamide and bicalutamide, are used to treat prostate cancer. It would therefore be useful to have available compounds that can activate ("agonize") the function of the AR in a tissue-selective manner that would produce the desired osteo- and myoanabolic effects of androgens without the negative androgenic properties, such as virilization and repression of high density lipoprotein cholesterol (HDL).

The beneficial effects of androgens on bone in postmenopausal osteoporosis were documented in recent studies using combined testosterone and estrogen administration [Hofbauer, et al., Eur. J. Edocrinol. 140: 271-286 (1999)]. In a large 2-year, double-blind comparison study, oral conjugated estrogen (CEE) and methyltestosterone combinations were demonstrated to be effective in promoting accrual of bone mass in the spine and hip, while conjugated estrogen therapy alone prevented bone loss [J. Reprod. Med., 44: 1012-1020 (1999)].

Additionally, there is evidence that hot flushes decrease in women treated with CEE and methyltestosterone; however, 30% of the treated women suffered from significant increases in acne and facial hair, a complication of all current androgen pharmacotherapies [Watts, et al., Obstet. Gynecol., 85: 529-537 (1995)]. It was also found that the addition of methyltestosterone to CEE decreased HDL levels, as seen in other studies. Thus, the virilizing potential and effects on lipid profile of current androgen therapies provide a rationale for developing tissue-selective androgen receptor agonists.

Androgens play an important role in bone metabolism in men [Anderson, et al., "Androgen supplementation in eugonadal men with osteoporosis – effects of six months of treatment on bone mineral density and cardiovascular risk factors," Bone, 18: 171-177 (1996)]. Even in eugonadal men with osteoporosis, the therapeutic response to testosterone treatment reveals that androgens exert important osteoanabolic effects. Mean lumbar BMD increased from 0.799 gm/cm2 to 0.839 g/cm2, in 5 to 6 months in response to 250 mg of testosterone ester administered intramuscularly. SARMs can thus be used to treat osteoporosis in men.

Androgen deficiency occurs in men with stage D prostate cancer (metastatic) who undergo androgen deprivation therapy (ADT). Endocrine orchiectomy is achieved by long acting GnRH agonists, while androgen receptor blockade is implemented with AR antagonists. In response to hormonal deprivation, these men suffered from hot flushes, significant bone loss, weakness, and fatigue. In a pilot study of men with stage D prostate cancer, osteopenia (50% vs. 38%) and osteoporosis (38% vs. 25%) were more common in men who had undergone ADT for greater than one year than the patients who did not undergo ADT [Wei, et al., Urology, 54: 607-611 (1999)]. Lumbar spine BMD was significantly lower in men who had undergone ADT. Thus tissue selective AR antagonists in the prostate that lack antagonistic action in bone and muscle can be useful agents for the treatment of prostate cancer, either alone or as an adjunct to traditional ADT [See also A. Stoch, et al., J. Clin. Endocrin. Metab., 86: 2787-2791 (2001)].

Tissue-selective AR antagonists can also treat polycystic ovarian syndrome in postmenopausal women. See C.A. Eagleson, et al., "Polycystic ovarian syndrome: evidence that flutamide restores sensitivity of the gonadotropin-releasing hormone pulse generator to inhibition by estradiol and progesterone," J. Clin. Endocrinol. Metab., 85: 4047-4052 (2000).

SARMs can also treat certain hematopoietic disorders as androgens stimulate renal hypertrophy and erythropoietin (EPO) production. Prior to the introduction of recombinant human EPO, androgens were employed to treat anemia caused by chronic renal failure. In addition, androgens increase serum EPO levels in anemic patients with non-severe aplastic anemia and myelodysplastic syndromes. Treatment for anemia will require selective action such as can be provided by SARMs.

SARMs can also have clinical value as an adjunct to the treatment of obesity. This approach to lowering body fat is supported by published observations that androgen administration reduced subcutaneous and visceral fat in obese patients [J.C. Lovejoy, et al., "Oral anabolic steroid treatment, but not parenteral androgen treatment, decreases abdominal fat in obese, older men," Int. J. Obesity, 19: 614-624 (1995)], [J.C. Lovejoy, et al., "Exogenous Androgens Influence Body Composition and Regional Body Fat Distribution in Obese Postmenopausal Women – A Clinical Research Center Study," J. Clin. Endocrinol. Metab., 81: 2198-2203 (1996)]. Therefore, SARMs devoid of unwanted androgenic effects can be beneficial in the treatment of obesity.

Androgen receptor agonists can also have therapeutic value against neurodegenerative diseases such as Alzheimer's disease (AD). The ability of androgens to induce neuroprotection through the androgen receptor was reported by J. Hammond, et al., "Testosterone-mediated neuroprotection through the androgen receptor in human primary neurons," J. Neurochem., 77: 1319-1326 (2001). Gouras et al. reported that testosterone reduces secretion of Alzheimer's β-amyloid peptides and can therefore be used in the treatment of AD [(Proc. Nat. Acad. Sci., 97: 1202-1205 (2000)]. A mechanism via inhibition of hyperphosphorylation of proteins implicated in the progression AD has also been described [S. Papasozomenos, "Testosterone prevents the heat shock-induced over activation of glycogen synthase kinase-3β but not of cyclin-dependent kinase 5 and c-Jun NH2-terminal kinase and concomitantly abolishes hyperphosphorylation of τ: Implications for Alzheimer's disease," Proc. Nat. Acad. Sci., 99: 1140-1145 (2002)].

Androgen receptor agonists can also have a beneficial effect on muscle tone and strength. Recent studies have demonstrated that "physiologic androgen replacement in healthy, hypogonadal men is associated with significant gains in fat-free mass, muscle size and maximal voluntary strength," [S. Bhasin, et al., J. Endocrin., 170: 27-38 (2001)].

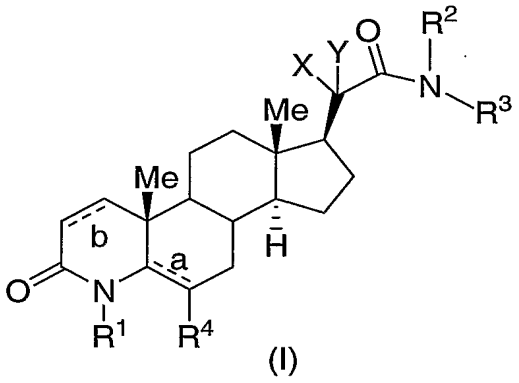
Androgen receptor modulators can be useful in treating decreased libido in both men and women. Androgen deficiency in men is related to diminished libido. S. Howell et al., Br. J. Cancer, 82:

158-161. Low androgen levels contribute to the decline in sexual interest in many women during their later reproductive years. S. Davis, J. Clin. Endocrinol. Metab., 84: 1886-1891 (1999). In one study, circulating free testosterone was positively correlated with sexual desire. Id. In another study, women with primary or secondary adrenal insufficiency were provided physiological DHEA replacement (50 mg/day). Compared with women taking placebo, DHEA-administered women showed an increase in the frequency of sexual thoughts, interest, and satisfaction. W. Arlt, et al., N Engl. J. Med. 341:1013-1020 (1999), see also, K. Miller, J. Clin. Endocrinol. Metab., 86: 2395-2401 (2001).

Additionally, androgen receptor modulators may also be useful in treating cognitive impairment. In a recent study, high-dose oral estrogen either alone or in combination with high-dose oral methyltestosterone was given to postmenopausal women for a four-month period. Cognitive tests were administered before and after the four-month hormone treatment. The investigation found that women receiving a combination of estrogen (1.25 mg) and methyltestosterone (2.50 mg) maintained a steady level of performance on the Building Memory task, but the women receiving estrogen (1.25 mg) alone exhibited decreased performance. A. Wisniewski, Horm. Res. 58:150-155 (2002).

SUMMARY OF THE INVENTION

The present invention relates to compounds of structural formula I:



(I)

or a pharmaceutically acceptable salt or stereoisomer thereof, their uses and pharmaceutical compositions.

These compounds are effective as androgen receptor agonists and are particularly effective as SARMs. They are therefore useful for the treatment of conditions caused by androgen deficiency or which can be ameliorated by androgen administration.

The present invention also relates to pharmaceutical compositions comprising the compounds of the present invention and a pharmaceutically acceptable carrier.

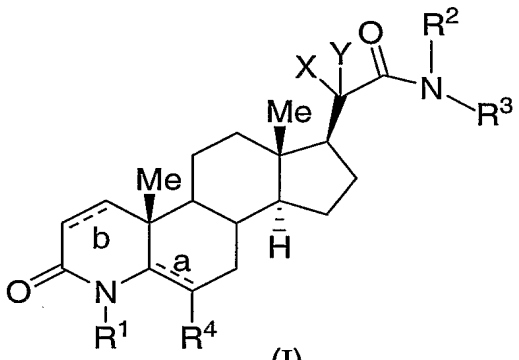
In this invention, we have identified compounds that function as SARMs using a series of in vitro cell-assays that profile ligand mediated activation of AR, such as (i) N-C interaction, (ii) transcriptional repression, and (iii) transcriptional activation. SARM compounds in this invention, identified with the methods listed above, exhibit tissue selective AR agonism in vivo, i.e. agonism in bone (stimulation of bone formation in a rodent model of osteoporosis) and antagonism in prostate (minimal effects on prostate growth in castrated rodents and antagonism of prostate growth induced by AR agonists).

The compounds of the present invention identified as SARMs are useful to treat diseases or conditions caused by androgen deficiency which can be ameliorated by androgen administration. Such compounds are ideal for the treatment of osteoporosis in women and men as a monotherapy or in combination with inhibitors of bone resorption, such as bisphosphonates, estrogens, SERMs, cathepsin K inhibitors, $\alpha v\beta 3$ integrin receptor antagonists, calcitonin, and proton pump inhibitors. They can also be used with agents that stimulate bone formation, such as parathyroid hormone or analogs thereof. The SARM compounds of the present invention can also be employed for treatment of prostate disease, such as prostate cancer and benign prostatic hyperplasia (BPH). Moreover, compounds of this invention exhibit minimal effects on skin (acne and facial hair growth) and can be useful for treatment of hirsutism. Additionally, compounds of this invention can stimulate muscle growth and can be useful for treatment of sarcopenia and frailty. They can be employed to reduce visceral fat in the treatment of obesity. Moreover, compounds of this invention can exhibit androgen agonism in the central nervous system and can be useful to treat vasomotor symptoms (hot flush) and to increase energy and libido. They can be used in the treatment of Alzheimer's disease.

The compounds of the present invention can also be used in the treatment of prostate cancer, either alone or as an adjunct to GnRH agonist/antagonist therapy, for their ability to restore bone, or as a replacement for antiandrogen therapy because of their ability to antagonize androgen in the prostate, and minimize bone depletion. Further, the compounds of the present invention can be used for their ability to restore bone in the treatment of pancreatic cancer as an adjunct to treatment with antiandrogen, or as monotherapy for their antiandrogenic properties, offering the advantage over traditional antiandrogens of being bone-sparing. Additionally, compounds of this invention can increase the number of blood cells, such as red blood cells and platelets, and can be useful for the treatment of hematopoietic disorders, such as aplastic anemia. Thus, considering their tissue selective androgen receptor agonism listed above, the compounds of this invention are ideal for hormone replacement therapy in hypogonadic (androgen deficient) men.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to compounds that are useful as androgen receptor modulators, in particular, as selective androgen receptor modulators (SARMs). Compounds of the present invention are described by structural formula I:



(I)

a pharmaceutically acceptable salt or a stereoisomer thereof, wherein:

n is 0, 1, or 2;

a and b are each independently chosen from a double bond and a single bond;

X and Y are each independently chosen from hydrogen, halogen, hydroxy, C_{1-4} alkoxy, hydroxymethyl, and C_{1-3} alkyl, wherein said alkoxy and alkyl are each optionally substituted with one to seven fluorine atoms; or

X and Y, together with the carbon atom to which they are attached, can optionally form a C_{3-6} cycloalkyl group;

R^1 is chosen from hydrogen, carbonyl(C_{1-3} alkyl), hydroxy, C_{1-4} alkoxy, halogen, hydroxymethyl, (C_{0-6} alkyl)$_2$amino, and C_{1-3} alkyl, wherein said alkoxy and alkyl are each optionally substituted with one to seven fluorine atoms;

R^4 is chosen from halogen, C_{1-6} alkyl, C_{2-6} alkenyl, C_{2-6} alkynyl, $(CH_2)_n$-phenyl, and $(CH_2)_n$-naphthyl; and wherein R^4 is optionally substituted with one or more substituents each independently chosen from cyano, carboxy, halogen, hydroxy, oxo, C_{1-4} alkoxy, and C_{1-4} alkylthio; or

R^4, together with the carbon atom to which it is attached, form a carbonyl or a cyclopropyl group and provided that a represents a single bond; or

R^1 and R^4, together with the atoms to which they are attached, form a 5- or 6-membered ring system optionally containing an additional heteroatom chosen from O, S, and NC_{1-4} alkyl;

R^2 is hydrogen or C_{1-4} alkyl, wherein said C_{1-4} alkyl is optionally substituted with one or more substituents independently selected from halogen, hydroxy, C_{1-4} alkoxy, and C_{1-4} alkylamino;

R^3 is selected from

$(CH_2)_n$-aryl, wherein said aryl is optionally substituted with one or more substituents independently chosen from R^5,

$(CH_2)_n$-heteroaryl, wherein said heteroaryl is optionally substituted with one or more substituents independently chosen from R^5, and

C_{1-10} alkyl, wherein said C_{1-10} alkyl is optionally substituted with one or more substituents independently chosen from R^6; or

R^2 and R^3, together with the nitrogen atom to which they are attached, form a 5- or 6-membered saturated ring fused with a 5- or 6-membered aromatic ring system having 0, 1, or 2 heteroatoms selected from N, O, and S; and

wherein any methylene (CH_2) carbon atom in $(CH_2)_n$ is optionally substituted with one or more groups independently selected from halogen, hydroxy, and C_{1-4} alkyl optionally substituted with one or more halogen moieties; or two substituents when on the same methylene (CH_2) group are taken together with the carbon atom to which they are attached to form a cyclopropyl group;

R^5 is chosen from: hydrogen, halogen, $(carbonyl)_{0-1}C_{1-10}$ alkyl, $(carbonyl)_{0-1}C_{2-10}$ alkenyl,

$(carbonyl)_{0-1}C_{2-10}$ alkynyl, C_{3-8} cycloalkyl C_{0-10} alkyl$(carbonyl)_{0-1}$,

C_{3-8} heterocycloalkyl C_{0-10} alkyl$(carbonyl)_{0-1}$,

C_{1-4}acylamino C_{0-10} alkyl, C_{0-10} alkylamino C_{0-10} alkyl,

C_{0-10} alkylamino C_{0-10} alkylaminocarbonyl, di-(C_{1-10} alkyl)amino C_{0-10} alkyl,

arylC_{0-10} alkylamino C_{0-10} alkyl, (arylC_{0-10} alkyl)$_2$amino C_{0-10} alkyl,

C_{3-8} cycloalkyl C_{0-10} alkylamino C_{0-10} alkyl,

C_{3-8} heterocyclyl C_{0-10} alkylamino C_{0-10} alkyl,

(C_{3-8} cycloalkyl C_{0-10} alkyl)$_2$amino C_{0-10} alkyl,

(C_{3-8} heterocyclyl C_{0-10} alkyl)$_2$amino C_{0-10} alkyl,

C_{3-8} cycloalkyl C_{0-10} alkyl aminocarbonylamino,

(C_{1-10} alkyl)$_2$aminocarbonylamino, (aryl C_{1-10} alkyl)$_{1-2}$aminocarbonylamino,

C_{0-10} alkyl aminocarbonylamino, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonylamino,

(C_{1-10} alkyl)$_2$aminocarbonyl C_{0-10} alkyl,

(aryl C_{1-10} alkyl)$_{1-2}$aminocarbonyl C_{0-10} alkyl,

C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl,

C_{3-8} cycloalkyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl,

C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl,

aryl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, (C_{1-10} alkyl)$_2$aminocarbonyl,

(aryl C_{1-10} alkyl)$_{1-2}$aminocarbonyl, C_{1-10} alkoxy (carbonyl)$_{0-1}C_{0-10}$ alkyl,

C_{0-10} alkyl carbonylamino(C_{0-10} alkyl), C_{0-10} alkoxy carbonylamino(C_{0-10} alkyl),

carboxy C_{0-10} alkylamino, carboxy C_{0-10} alkyl, carboxy C_{3-8} cycloalkyl, C_{1-10} alkoxy,

C_{1-10}alkyloxy C_{0-10}alkyl, C_{0-10}alkyl carbonylC_{0-10}alkoxy, C_{1-10} alkylcarbonyloxy,

C_{3-8} heterocyclyl C_{0-10} alkylcarbonyloxy, C_{3-8} cycloalkyl C_{0-10} alkylcarbonyloxy,

aryl C_{0-10} alkylcarbonyloxy, C_{1-10} alkylcarbonyloxy amino,

C_{3-8} heterocyclyl C_{0-10} alkylcarbonyloxy amino,

C_{3-8} cycloalkyl C_{0-10} alkylcarbonyloxy amino, aryl C_{0-10} alkylcarbonyloxy amino,

(C_{1-10} alkyl)$_2$aminocarbonyloxy, (aryl C_{0-10} alkyl)$_{1-2}$aminocarbonyloxy,

(C_{3-8} heterocyclyl C_{0-10} alkyl)$_{1-2}$aminocarbonyloxy,

(C_{3-8} cycloalkyl C_{0-10}alkyl)$_{1-2}$aminocarbonyloxy, hydroxy (carbonyl)$_{0-1}C_{0-10}$alkyl,

hydroxycarbonylC_{0-10}alkoxy, hydroxycarbonylC_{0-10}alkyloxy, C_{1-10} alkylthio,

C_{1-10} alkylsulfinyl, aryl C_{0-10} alkylsulfinyl, C_{3-8} heterocyclyl C_{0-10} alkylsulfinyl,

C_{3-8} cycloalkyl C_{0-10} alkylsulfinyl, C_{1-10} alkylsulfonyl, aryl C_{0-10} alkylsulfonyl,

C_{3-8} heterocyclyl C_{0-10} alkylsulfonyl, C_{3-8} cycloalkyl C_{0-10} alkylsulfonyl,

C_{1-10} alkylsulfonylamino, aryl C_{1-10} alkylsulfonylamino,

C_{3-8} heterocyclyl C_{1-10} alkylsulfonylamino, C_{3-8} cycloalkyl C_{1-10} alkylsulfonylamino, cyano,

nitro, perfluoroC_{1-6}alkyl, and perfluoroC_{1-6}alkoxy;

wherein R^5 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, O(C=O)C_1-C_6 alkyl, NO_2, trifluoromethoxy, trifluoroethoxy, -O_b(C_{1-10})perfluoroalkyl, and NH_2; and

R^6 is halogen, hydroxy, C_{1-4} alkoxy, $CONH_2$, and C_{1-4} alkylamino, wherein R^6 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, O(C=O)C_1-C_6 alkyl, NO_2, trifluoromethoxy, trifluoroethoxy, -O_b(C_{1-10})perfluoroalkyl, NH_2, and -O_b(C_{1-10})alkyl optionally substituted with one or more halogen moieties.

Illustrative but nonlimiting examples of compounds of the present invention are the following:

N-[3-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-cyanopyrid-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[6-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[3-cyano-pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(3-methyl-benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-nitro-benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(4-chloro-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-methyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-methoxy-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5,6-dimethyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(4-methyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-fluoropyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-cyclopropyl-1,3,4-thiadiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(2-methyl-3-bromo-pyrid-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N,N-methyl(pyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-methylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(5-chloropyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(1,3-pyrimid-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(1,3-pyrazin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(2-methyl-pyrid-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(pyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(pyridin-3-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(pyridin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[(3-carboxamido)-pyridin-6-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-cyanopyridin-3-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-methylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-aminopyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[(6-trifluoromethyl)-pyrid-3-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-ethylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(6-fluoro-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(2-ethylpyridin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(2-ethylpyridin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(2-methyl-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-(pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(pyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(pyridin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-cyanopyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-aminopyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(6-trifluoromethyl)-pyrid-3-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(2-chloro-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-fluoro-pyrid-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-ethylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-cyclopropyl-1,3,4-thiadiazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(2-methyl-3-bromo-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N , *N* -methyl(pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-chloropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(1,3-pyrimid-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(1,3-pyrazin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-fluoropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(benzimidazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(5-carboxyl)-pyrid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(4-carboxyl)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(4-carboxyl-3-chloro)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[2-chloro(4-methoxycarbonyl)phenyl]-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(1,3-pyrimid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[5-(ethoxycarbonyl) -1,3-thiazol-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[4-(trifluoromethyl)-5-(ethoxycarbonyl) -1,3-thiazol-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[4-hydroxy-5-(ethoxycarbonyl) -1,3-pyrimid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-methylpyridin-2-yl)-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(4-carboxamido)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(2-methyl-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(pyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(4,6-dimethylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(benzimidazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(6-cyanopyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-fluoropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -(5-chloropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N -[(5-carboxyl)-pyrid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide;

N-[(5-cyclopropyl-1,3,4-thiadiazol-2-yl] - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-[4,6-dimethyl-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-(benzimidazol-2-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-[5-cyano-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-(1,3-pyrimid-4-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-[3-methyl-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-[(5-carboxamido)pyrid2-l] -- 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-(isoquinolin-3-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-[6-(trifluoromethyl)pyridin-2-yl]- 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

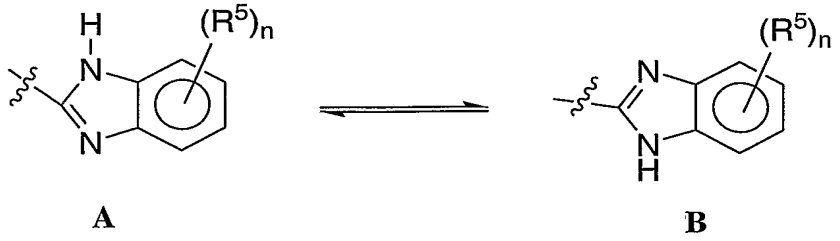
N-(4-azabenzimidazol-2-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide;

N-(1H-imidazo[4,5-b] pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide; and pharmaceutically acceptable salts and stereoisomers thereof.

The compounds of the present invention can have asymmetric centers, chiral axes, and chiral planes (as described in: E.L. Eliel and S.H. Wilen, *Stereochemistry of Carbon Compounds*, John Wiley & Sons, New York, 1994, pages 1119-1190), and occur as racemates, racemic mixtures, and as individual diastereomers, with all possible isomers and mixtures thereof, including optical isomers, being included in the present invention.

In addition, the compounds disclosed herein can exist as tautomers and both tautomeric forms are intended to be encompassed by the scope of the invention, even though only one tautomeric structure is depicted. For example, any claim to compound A below is understood to include tautomeric

structure B, and vice versa, as well as mixtures thereof. The term ~~~ represents the remainder of the 4-azasteroid derivatives of the present invention.



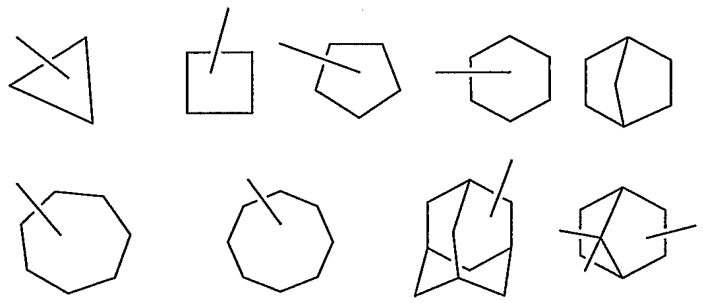
A B

The term "alkyl" shall mean straight or branched chain alkanes of one to ten total carbon atoms, or any number within this range (i.e., methyl, ethyl, 1-propyl, 2-propyl, n-butyl, s-butyl, t-butyl, etc.). The term "C_0 alkyl" (as in "C_{0-8} alkylaryl") shall refer to the absence of an alkyl group.

The term "alkenyl" shall mean straight or branched chain alkenes of two to ten total carbon atoms, or any number within this range.

The term "alkynyl" refers to a hydrocarbon radical straight, branched or cyclic, containing from 2 to 10 carbon atoms and at least one carbon to carbon triple bond. Up to three carbon-carbon triple bonds can be present. Thus, "C_2-C_6 alkynyl" means an alkynyl radical having from 2 to 6 carbon atoms. Alkynyl groups include ethynyl, propynyl, butynyl, 3-methylbutynyl and so on. The straight, branched or cyclic portion of the alkynyl group can contain triple bonds and can be substituted if a substituted alkynyl group is indicated.

"Cycloalkyl" as used herein is intended to include non-aromatic cyclic hydrocarbon groups, having the specified number of carbon atoms, which may or may not be bridged or structurally constrained. Examples of such cycloalkyls include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, adamantyl, cyclooctyl, cycloheptyl, tetrahydro-naphthalene, methylenecylohexyl, and the like. As used herein, examples of "$C_3 - C_{10}$ cycloalkyl" can include, but are not limited to:



"Alkoxy" represents either a cyclic or non-cyclic alkyl group of indicated number of carbon atoms attached through an oxygen bridge. "Alkoxy" therefore encompasses the definitions of alkyl and cycloalkyl above.

"Perfluoroalkyl" represents alkyl chains of up to 10 carbon atoms having exhaustive substitution of their corresponding hydrogens with fluorine atoms.

As used herein, "aryl" is intended to mean any stable monocyclic or bicyclic carbon ring of up to 7 atoms in each ring, wherein at least one ring is aromatic. Examples of such aryl elements include, but are not limited to, phenyl, naphthyl, tetrahydro-naphthyl, indanyl, or biphenyl. In cases where the aryl substituent is bicyclic and one ring is non-aromatic, it is understood that attachment is via the aromatic ring.

The term heteroaryl, as used herein, represents a stable monocyclic or bicyclic ring of up to 7 atoms in each ring, wherein at least one ring is aromatic and contains from 1 to 4 heteroatoms chosen from O, N and S. Heteroaryl groups within the scope of this definition include but are not limited to: azabenzimidazole, acridinyl, carbazolyl, cinnolinyl benzimidazolyl, benzofuranyl, benzothiophenyl, benzoxazolyl, benzothiazolyl, benzodihydrofuranyl, 1,3-benzodioxolyl, 2,3-dihydro-1,4-benzodioxinyl, indolyl, quinolyl, quinoxalinyl, isoquinolyl, furanyl, thienyl, imidazolyl, oxazolyl, thiazolyl, isoxazolyl, isothiazolyl, pyrazolyl, pyrrolyl, pyridyl, pyrimidyl, pyrazinyl, piridazinyl, tetrahydroquinolinyl, thiadiazolyl, oxadiazolyl, triazolyl, imidizopyridinyl, tetrazolyl, and indanyl. As with the definition of heterocycle below, "heteroaryl" is also understood to include the N-oxide derivative of any nitrogen-containing heteroaryl. In cases where the heteroaryl substituent is bicyclic and one ring is non-aromatic or contains no heteroatoms, it is understood that attachment is via the aromatic ring or via the heteroatom containing ring, respectively.

Whenever the term "alkyl" or "aryl" or either of their prefix roots appears in a name of a substituent (e.g., aryl C_{0-8} alkyl), it shall be interpreted as including those limitations given above for "alkyl" and "aryl." Designated numbers of carbon atoms (e.g., C_{0-8}) shall refer independently to the number of carbon atoms in an alkyl or cyclic alkyl moiety or to the alkyl portion of a larger substituent in which alkyl appears as its prefix root.

As appreciated by those of skill in the art, "halo" or "halogen" as used herein is intended to include chloro, fluoro, bromo and iodo.

The term "heterocycle" or "heterocyclyl" as used herein is intended to mean a 5- to 10-membered aromatic or nonaromatic heterocycle containing from 1 to 4 heteroatoms selected from the group consisting of O, N and S, and includes bicyclic groups. "Heterocyclyl" therefore includes the above mentioned heteroaryls, as well as dihydro and tetrathydro analogs thereof. Further examples of "heterocyclyl" include, but are not limited to the following: azabenzimidazole, benzoimidazolyl,

benzofuranyl, benzofurazanyl, benzopyrazolyl, benzotriazolyl, benzothiophenyl, benzoxazolyl, carbazolyl, carbolinyl, cinnolinyl, furanyl, imidazolyl, indolinyl, indolyl, indolazinyl, indazolyl, isobenzofuranyl, isoindolyl, isoquinolyl, isothiazolyl, isoxazolyl, naphthpyridinyl, oxadiazolyl, oxazolyl, oxazoline, isoxazoline, oxetanyl, pyranyl, pyrazinyl, pyrazolyl, pyridazinyl, pyridopyridinyl, pyridazinyl, pyridinyl, pyrimidyl, pyrrolyl, quinazolinyl, quinolyl, quinoxalinyl, tetrahydropyranyl, tetrazolyl, tetrazolopyridyl, thiadiazolyl, thiazolyl, thienyl, triazolyl, azetidinyl, aziridinyl, 1,4-dioxanyl, hexahydroazepinyl, piperazinyl, piperidinyl, pyrrolidinyl, morpholinyl, thiomorpholinyl, dihydrobenzoimidazolyl, dihydrobenzofuranyl, dihydrobenzothiophenyl, dihydrobenzoxazolyl, dihydrofuranyl, dihydroimidazolyl, dihydroindolyl, dihydroisooxazolyl, dihydroisothiazolyl, dihydrooxadiazolyl, dihydrooxazolyl, dihydropyrazinyl, dihydropyrazolyl, dihydropyridinyl, dihydropyrimidinyl, dihydropyrrolyl, dihydroquinolinyl, dihydrotetrazolyl, dihydrothiadiazolyl, dihydrothiazolyl, dihydrothienyl, dihydrotriazolyl, dihydroazetidinyl, methylenedioxybenzoyl, tetrahydrofuranyl, and tetrahydrothienyl, and N-oxides thereof. Attachment of a heterocyclyl substituent can occur via a carbon atom or via a heteroatom.

The terms "arylalkyl" and "alkylaryl" include an alkyl portion where alkyl is as defined above and include an aryl portion where aryl is as defined above. Examples of arylalkyl include, but are not limited to, benzyl, phenylethyl, phenylpropyl, naphthylmethyl, and naphthylethyl. Examples of alkylaryl include, but are not limited to, toluene, ethylbenzene, propylbenzene, methylpyridine, ethylpyridine, propylpyridine and butylpyridine.

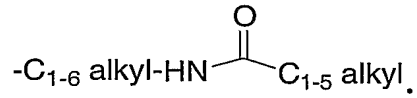
The term "oxy" means an oxygen (O) atom. The term "thio" means a sulfur (S) atom. The term "oxo" means "=O". The term "carbonyl" means "C=O."

The term "substituted" shall be deemed to include multiple degrees of substitution by a named substituent. Where multiple substituent moieties are disclosed or claimed, the substituted compound can be independently substituted by one or more of the disclosed or claimed substituent moieties, singly or plurally. By independently substituted, it is meant that the (two or more) substituents can be the same or different.

When any variable (e.g., R^5, R^6, etc.) occurs more than one time in any substituent or in formula I, its definition in each occurrence is independent of its definition at every other occurrence. Also, combinations of substituents and/or variables are permissible only if such combinations result in stable compounds.

Under standard nomenclature used throughout this disclosure, the terminal portion of the designated side chain is described first, followed by the adjacent functionality toward the point of

attachment. For example, a C_{1-5} alkylcarbonylamino C_{1-6} alkyl substituent is equivalent to



In choosing compounds of the present invention, one of ordinary skill in the art will recognize that the various substituents, i.e. R^1, R^2, R^3, R^4, R^5 etc., are to be chosen in conformity with well-known principles of chemical structure connectivity.

Lines drawn into the ring systems from substituents indicate that the indicated bond can be attached to any of the substitutable ring atoms. If the ring system is polycyclic, it is intended that the bond be attached to any of the suitable carbon atoms on the proximal ring only.

It is understood that substituents and substitution patterns on the compounds of the instant invention can be selected by one of ordinary skill in the art to provide compounds that are chemically stable and that can be readily synthesized by techniques known in the art, as well as those methods set forth below, from readily available starting materials. If a substituent is itself substituted with more than one group, it is understood that these multiple groups can be on the same carbon or on different carbons, so long as a stable structure results. The phrase "optionally substituted with one or more substituents" should be taken to be equivalent to the phrase "optionally substituted with at least one substituent" and in such cases one embodiment will have from zero to three substituents.

In one embodiment of the invention, X and Y are each independently chosen from hydrogen, halogen, and C_{1-3} alkyl, wherein said alkyl is optionally substituted with one to seven fluorine atoms. In another embodiment of the invention, X and Y are each independently chosen from hydroxy, C_{1-4} alkoxy, hydroxymethyl, and hydrogen, wherein said alkoxy is optionally substituted with one to seven fluorine atoms.

In yet another embodiment of the invention, X and Y, together with the carbon atom to which they are attached, can optionally form a C_{3-6} cycloalkyl group, such as for example a cyclopropyl or cyclopentyl group.

In one embodiment of the invention, R^1 is chosen from hydrogen, carbonyl(C_{1-3} alkyl), hydroxy, C_{1-4} alkoxy, and C_{1-3} alkyl, wherein said alkoxy and alkyl are each optionally substituted with one to seven fluorine atoms. In one embodiment of the invention, R^1 is chosen from hydrogen, (C_{0-6} alkyl)$_2$amino C_{0-6}alkyl, and C_{1-3} alkyl, wherein said alkyl is optionally substituted with one to seven fluorine atoms. In a variant of this embodiment, R^1 is chosen from hydrogen, CF_3, and C_{1-3} alkyl. In another variant, R^1 is methyl.

In yet another embodiment of the invention, R^4 is chosen from halogen, C_{1-6} alkyl, and $(CH_2)_n$-phenyl, wherein R^4 is optionally substituted with one or more substituents each independently chosen from cyano, carboxy, halogen, hydroxy, oxo, C_{1-4} alkoxy, and C_{1-4} alkylthio. In a variant of this embodiment R^4 is chosen from halogen, and C_{1-6} alkyl, such as for example, CH_3.

In another embodiment of the invention, R^4, together with the carbon atom to which it is attached, form a carbonyl or a cyclopropyl group and provided that a represents a single bond. In yet another embodiment of the invention, R^1 and R^4, together with the atoms to which they are attached, form a 5- or 6-membered ring system optionally containing an additional heteroatom chosen from O, S, and NC_{1-4} alkyl.

In one embodiment of the invention, R^2 is hydrogen. In another embodiment of the invention, R^2 is C_{1-4} alkyl, such as for example, methyl or ethyl, wherein said C_{1-4} alkyl is optionally substituted with one or more substituents independently selected from halogen, hydroxy, C_{1-4} alkoxy, and C_{1-4} alkylamino.

In another embodiment, R^3 is selected from $(CH_2)_n$-aryl, wherein said aryl is optionally substituted with one or more substituents independently chosen from R^5, and $(CH_2)_n$-heteroaryl, wherein said heteroaryl is optionally substituted with one or more substituents independently chosen from R^5. In another embodiment of the invention, R^3 is C_{1-10} alkyl, wherein said C_{1-10} alkyl is optionally substituted with one or more substituents independently chosen from R^6.

In yet another embodiment of the invention, R^2 and R^3, together with the nitrogen atom to which they are attached, form a 5- or 6-membered saturated ring fused with a 5- or 6-membered aromatic ring system having 0, 1, or 2 heteroatoms selected from N, O, and S.

In one embodiment of the invention, R^5 is chosen from: hydrogen, halogen, (carbonyl)$_{0-1}C_{1-10}$ alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{3-8} heterocycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{0-10} alkylamino C_{0-10} alkyl, C_{0-10} alkylamino C_{0-10} alkylaminocarbonyl, arylC_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} heterocyclyl C_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl aminocarbonylamino, C_{0-10} alkyl aminocarbonylamino, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonylamino, C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, aryl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, $(C_{1-10}$ alkyl$)_2$aminocarbonyl, C_{1-10} alkoxy (carbonyl)$_{0-1}C_{0-10}$ alkyl, C_{0-10} alkyl carbonylamino(C_{0-10} alkyl), C_{0-10} alkoxy carbonylamino(C_{0-10} alkyl), carboxy C_{0-10} alkylamino, carboxy C_{0-10} alkyl, carboxy C_{3-8} cycloalkyl,

C_{1-10} alkoxy, hydroxy (carbonyl)$_{0-1}C_{0-10}$alkyl, C_{0-10}alkyl carbonylC_{0-10}alkoxy, hydroxycarbonylC_{0-10}alkoxy, hydroxycarbonylC_{0-10}alkyloxy, cyano, nitro, perfluoroC_{1-6}alkyl, and perfluoroC_{1-6}alkoxy; wherein R^5 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, O(C=O)C_1-C_6 alkyl, NO_2, trifluoromethoxy, trifluoroethoxy, -O_b(C_{1-10})perfluoroalkyl, and NH_2.

In another embodiment, R^5 is chosen from: hydrogen, halogen, (carbonyl)$_{0-1}C_{1-10}$ alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{3-8} heterocycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{0-10} alkylamino C_{0-10} alkyl, C_{0-10} alkylamino C_{0-10} alkylaminocarbonyl, arylC_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} heterocyclyl C_{0-10} alkylamino C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl, C_{0-10} alkyl aminocarbonylamino, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonylamino, C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, (C_{1-10} alkyl)$_2$aminocarbonyl, C_{1-10} alkoxy (carbonyl)$_{0-1}C_{0-10}$ alkyl, C_{0-10} alkyl carbonylamino(C_{0-10} alkyl), C_{0-10} alkoxy carbonylamino(C_{0-10} alkyl), carboxy C_{0-10} alkylamino, carboxy C_{0-10} alkyl, carboxy C_{3-8} cycloalkyl, C_{1-10} alkoxy, hydroxy (carbonyl)$_{0-1}C_{0-10}$alkyl, hydroxycarbonylC_{0-10}alkoxy, C_{0-10}alkyl carbonylC_{0-10}alkoxy hydroxycarbonylC_{0-10}alkyloxy, cyano, nitro, perfluoroC_{1-6}alkyl, and perfluoroC_{1-6}alkoxy; wherein R^5 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, O(C=O)C_1-C_6 alkyl, NO_2, trifluoromethoxy, trifluoroethoxy, -O_b(C_{1-10})perfluoroalkyl, and NH_2.

In yet another embodiment, R^5 is chosen from: hydrogen, halogen, (carbonyl)$_{0-1}C_{1-10}$ alkyl, C_{3-8} cycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{3-8} heterocycloalkyl C_{0-10} alkyl(carbonyl)$_{0-1}$, C_{0-10} alkylamino C_{0-10} alkyl, C_{0-10} alkylamino C_{0-10} alkylaminocarbonyl, C_{3-8} cycloalkyl C_{0-10} alkyl, C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{3-8} heterocyclyl C_{0-10} alkyl aminocarbonyl C_{0-10} alkyl, C_{1-10} alkoxy (carbonyl)$_{0-1}C_{0-10}$ alkyl, C_{0-10} alkyl carbonylamino(C_{0-10} alkyl), C_{0-10} alkoxy carbonylamino(C_{0-10} alkyl), carboxy C_{0-10} alkylamino, C_{1-10} alkoxy, C_{0-10}alkyl carbonylC_{0-10}alkoxy, hydroxy (carbonyl)$_{0-1}C_{0-10}$alkyl, hydroxycarbonylC_{0-10}alkoxy, hydroxycarbonylC_{0-10}alkyloxy, cyano, nitro, perfluoroC_{1-6}alkyl, and perfluoroC_{1-6}alkoxy; wherein R^5 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, O(C=O)C_1-C_6 alkyl, NO_2, trifluoromethoxy, trifluoroethoxy, -O_b(C_{1-10})perfluoroalkyl, and NH_2.

In one embodiment, R^6 is halogen, hydroxy, C_{1-4} alkoxy, $CONH_2$, and C_{1-4} alkylamino, wherein R^6 is optionally substituted with one or more groups chosen from: OH, (C_{1-6})alkoxy, halogen, CO_2H, CN, trifluoromethoxy, trifluoroethoxy, NH_2, and $-O_b(C_{1-10})$alkyl optionally substituted with one or more halogen moieties.

Compounds of the present invention have been found to be tissue- selective modulators of the androgen receptor (SARMs). In one aspect, compounds of the present invention can be useful to activate the function of the androgen receptor in a mammal, and in particular to activate the function of the androgen receptor in bone and/or muscle tissue and block or inhibit ("antagonize") the function of the androgen receptor in the prostate of a male individual or in the uterus of a female individual.

A further aspect of the present invention is the use of compounds of formula I to attenuate or block the function of the androgen receptor in the prostate of a male individual or in the uterus of a female individual induced by AR agonists, but not in hair-growing skin or vocal cords, and activate the function of the androgen receptor in bone and/or muscle tissue, but not in organs which control blood lipid levels (e.g. liver).

Representative compounds of the present invention typically display submicromolar binding affinity for the androgen receptor. Compounds of this invention are therefore useful in treating mammals suffering from disorders related to androgen receptor function. Therapeutically effective amounts of the compound, including the pharmaceutically acceptable salts thereof, are administered to the mammal, to treat disorders related to androgen receptor function, such as, androgen deficiency, disorders which can be ameliorated by androgen replacement, or which can be improved by androgen replacement, including: enhancement of weakened muscle tone, osteoporosis, osteopenia, glucocorticoid-induced osteoporosis, periodontal disease, bone fracture (for example, vertebral and non-vertebral fractures), bone damage following bone reconstructive surgery, sarcopenia, frailty, aging skin, male hypogonadism, postmenopausal symptoms in women, atherosclerosis, hypercholesterolemia, hyperlipidemia, obesity, aplastic anemia and other hematopoietic disorders, pancreatic cancer, inflammatory arthritis and joint repair, HIV-wasting, prostate cancer, benign prostatic hyperplasia (BPH), cancer cachexia, Alzheimer's disease, muscular dystrophies, cognitive decline, sexual dysfunction, sleep apnea, depression, premature ovarian failure, and autoimmune disease. Treatment is effected by administration of a therapeutically effective amount of a compound of structural formula I to a mammal in need of such treatment. In addition, these compounds are useful as ingredients in pharmaceutical compositions alone or in combination with other active agents.

In one embodiment, the compounds of the present invention can be used to treat conditions in a male individual which are caused by androgen deficiency or which can be ameliorated by androgen replacement, including, but not limited to, osteoporosis, osteopenia, glucocorticoid-induced

osteoporosis, periodontal disease, HIV-wasting, prostate cancer, cancer cachexia, obesity, arthritic conditions, anemias, such as for example, aplastic anemia, muscular dystrophies, and Alzheimer's disease, cognitive decline, sexual dysfunction, sleep apnea, depression, benign prostatic hyperplasia (BPH), and atherosclerosis, alone or in combination with other active agents. Treatment is effected by administration of a therapeutically effective amount of a compound of structural formula I to a male individual in need of such treatment.

"Arthritic condition" or "arthritic conditions" refers to a disease wherein inflammatory lesions are confined to the joints or any inflammatory conditions of the joints, most notably osteoarthritis and rheumatoid arthritis (Academic Press Dictionary of Science Technology; Academic Press; 1st edition, January 15, 1992). The compounds of Formula I are also useful, alone or in combination, to treat or prevent arthritic conditions, such as Behcet's disease; bursitis and tendinitis; CPPD deposition disease; carpal tunnel syndrome; Ehlers-Danlos syndrome; fibromyalgia; gout; infectious arthritis; inflammatory bowel disease; juvenile arthritis; lupus erythematosus; lyme disease; marfan syndrome; myositis; osteoarthritis; osteogenesis imperfecta; osteonecrosis; polyarteritis; polymyalgia rheumatica; psoriatic arthritis; Raynaud's phenomenon; reflex sympathetic dystrophy syndrome; Reiter's syndrome; rheumatoid arthritis; scleroderma; and Sjogren's syndrome. An embodiment of the invention encompasses the treatment or prevention of an arthritic condition which comprises administering a therapeutically effective amount of a Compound of Formula I. A subembodiment is the treatment or prevention of osteoarthritis, which comprises administering a therapeutically effective amount of a Compound of Formula I. See: Cutolo M, Seriolo B, Villaggio B, Pizzorni C, Craviotto C, Sulli A. Ann. N.Y. Acad. Sci. 2002 Jun;966:131-42; Cutolo, M. Rheum Dis Clin North Am 2000 Nov;26(4):881-95; Bijlsma JW, Van den Brink HR. Am J Reprod Immunol 1992 Oct-Dec;28(3-4):231-4; Jansson L, Holmdahl R.; Arthritis Rheum 2001 Sep;44(9):2168-75; and Purdie DW. Br Med Bull 2000; 56(3):809-23. Also, see Merck Manual, 17th edition, pp. 449-451.

When used in combination to treat arthritic conditions, the compounds of Formula I can be used with any of the drugs disclosed herein as useful for combination therapy, or can be used with drugs known to treat or prevent arthritic conditions, such as corticosteroids, cytoxic drugs (or other disease modifying or remission inducing drugs), gold treatment, methotrexate, NSAIDs, and COX-2 inhibitors.

In another embodiment, the compounds of the present invention can be used to treat conditions in a female individual which are caused by androgen deficiency or which can be ameliorated by androgen replacement, including, but not limited to, osteoporosis, osteopenia, aging skin, glucocorticoid-induced osteoporosis, postmenopausal symptoms, periodontal disease, HIV-wasting, cancer cachexia, obesity, anemias, such as for example, aplastic anemia, muscular dystrophies,

Alzheimer's disease, premature ovarian failure, cognitive decline, sexual dysfunction, depression, inflammatory arthritis and joint repair, atherosclerosis, and autoimmune disease, alone or in combination with other active agents. Treatment is effected by administration of a therapeutically effective amount of a compound of structural formula I to a female individual in need of such treatment.

The compounds of formula I are also useful in the enhancement of muscle tone in mammals, such as for example, humans. The compounds of structural formula I can also be employed as adjuncts to traditional androgen depletion therapy in the treatment of prostate cancer to restore bone, minimize bone loss, and maintain bone mineral density. In this manner, they can be employed together with traditional androgen deprivation therapy, including GnRH agonists/antagonists, such as those disclosed in P. Limonta, et al., Exp. Opin. Invest. Drugs, 10: 709-720 (2001); H.J. Stricker, Urology, 58 (Suppl. 2A): 24-27 (2001); R.P. Millar, et al., British Medical Bulletin, 56: 761-772 (2000); and A.V. Schally et al., Advanced Drug Delivery Reviews, 28: 157-169 (1997). The compounds of structural formula I can be used in combination with antiandrogens, such as flutamide, 2-hydroxyflutamide (the active metabolite of flutamide), nilutamide, and bicalutamide (Casodex™) in the treatment of prostate cancer.

Further, the compounds of the present invention can also be employed in the treatment of pancreatic cancer, either for their androgen antagonist properties or as an adjunct to an antiandrogen, such as flutamide, 2-hydroxyflutamide (the active metabolite of flutamide), nilutamide, and bicalutamide (Casodex™).

The term "treating cancer" or "treatment of cancer" refers to administration to a mammal afflicted with a cancerous condition and refers to an effect that alleviates the cancerous condition by killing the cancerous cells, but also to an effect that results in the inhibition of growth and/or metastasis of the cancer.

Compounds of structural formula I can minimize the negative effects on lipid metabolism. Therefore, considering their tissue selective androgen agonistic properties, the compounds of this invention exhibit advantages over existing approaches for hormone replacement therapy in hypogonadic (androgen deficient) male individuals.

Additionally, compounds of the present invention can increase the number of blood cells, such as red blood cells and platelets, and can be used for treatment of hematopoietic disorders, such as aplastic anemia.

In one embodiment of the invention, therapeutically effective amounts of the compound of Formula I, are administered to the mammal, to treat or improve disorders selected from enhancement of weakened muscle tone, osteoporosis, osteopenia, glucocorticoid-induced osteoporosis, periodontal disease, bone fracture, bone damage following bone reconstructive surgery, sarcopenia, frailty, aging

skin, male hypogonadism, postmenopausal symptoms in women, atherosclerosis, hypercholesterolemia, hyperlipidemia, obesity, aplastic anemia and other hematopoietic disorders, pancreatic cancer, inflammatory arthritis and joint repair, HIV-wasting, prostate cancer, benign prostatic hyperplasia (BPH), cancer cachexia, Alzheimer's disease, muscular dystrophies, cognitive decline, sexual dysfunction, sleep apnea, depression, premature ovarian failure, and autoimmune disease.

In another embodiment, therapeutically effective amounts of the compound can be used to treat or improve a disorder selected from weakened muscle tone, osteoporosis, osteopenia, glucocorticoid-induced osteoporosis, periodontal disease, bone fracture, bone damage following bone reconstructive surgery, sarcopenia, Alzheimer's disease, and frailty.

In another embodiment, the compound in accordance with the invention can be used to treat or improve a disorder such as male hypogonadism, postmenopausal symptoms in women, atherosclerosis, hypercholesterolemia, hyperlipidemia, obesity, aplastic anemia and other hematopoietic disorders, pancreatic cancer, inflammatory arthritis and joint repair, HIV-wasting, prostate cancer, benign prostatic hyperplasia (BPH), cancer cachexia, muscular dystrophies, cognitive decline, sexual dysfunction, sleep apnea, depression, premature ovarian failure, and autoimmune disease.

The compounds of the present invention can be administered in their enantiomerically pure form. Racemic mixtures can be separated into their individual enantiomers by any of a number of conventional methods. These include chiral chromatography, derivatization with a chiral auxiliary followed by separation by chromatography or crystallization, and fractional crystallization of diastereomeric salts.

As used herein, a compound of the present invention which functions as an "agonist" of the androgen receptor can bind to the androgen receptor and initiate a physiological or a pharmacological response characteristic of that receptor. The term "tissue-selective androgen receptor modulator" refers to an androgen receptor ligand that mimics the action of a natural ligand in some tissues but not in others. A "partial agonist" is an agonist which is unable to induce maximal activation of the receptor population, regardless of the amount of compound applied. A "full agonist" induces full activation of the androgen receptor population at a given concentration. A compound of the present invention which functions as an "antagonist" of the androgen receptor can bind to the androgen receptor and block or inhibit the androgen-associated responses normally induced by a natural androgen receptor ligand.

The term "pharmaceutically acceptable salts" refers to salts prepared from pharmaceutically acceptable non-toxic bases or acids including inorganic or organic bases and inorganic or organic acids. Non-limiting representive salts derived from inorganic bases include aluminum, ammonium, calcium, copper, ferric, ferrous, lithium, magnesium, manganic salts, manganous, potassium, sodium, zinc, and the like. In one variant of the invention, the salts are chosen from the ammonium,

calcium, lithium, magnesium, potassium, and sodium salts. Non-limiting examples of salts derived from pharmaceutically acceptable organic non-toxic bases include salts of primary, secondary, and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines, and basic ion exchange resins, such as arginine, betaine, caffeine, choline, N,N'-dibenzylethylenediamine, diethylamine, 2-diethylaminoethanol, 2-dimethylaminoethanol, ethanolamine, ethylenediamine, N-ethyl-morpholine, N-ethylpiperidine, glucamine, glucosamine, histidine, hydrabamine, isopropylamine, lysine, methylglucamine, morpholine, piperazine, piperidine, polyamine resins, procaine, purines, theobromine, triethylamine, trimethylamine, tripropylamine, tromethamine, and the like.

When the compound of the present invention is basic, salts can be prepared from pharmaceutically acceptable non-toxic acids, including inorganic and organic acids. Representative acids which can be employed include acetic, benzenesulfonic, benzoic, camphorsulfonic, citric, ethanesulfonic, formic, fumaric, gluconic, glutamic, hydrobromic, hydrochloric, isethionic, lactic, maleic, malic, mandelic, methanesulfonic, malonic, mucic, nitric, pamoic, pantothenic, phosphoric, propionic, succinic, sulfuric, tartaric, p-toluenesulfonic acid, trifluoroacetic acid, and the like. In one variant, the acids are selected from citric, fumaric, hydrobromic, hydrochloric, maleic, phosphoric, sulfuric, and tartaric acids.

The preparation of the pharmaceutically acceptable salts described above and other typical pharmaceutically acceptable salts is more fully described by Berg *et al.*, "Pharmaceutical Salts," *J. Pharm. Sci.*, 1977:66:1-19.

It would also be noted that the compounds of the present invention are potentially internal salts or zwitterions, since under physiological conditions a deprotonated acidic moiety in the compound, such as a carboxyl group, may be anionic, and this electronic charge might then be balanced off internally against the cationic charge of a protonated or alkylated basic moiety, such as a quaternary nitrogen atom.

The term "therapeutically effective amount" means the amount the compound of structural formula I that will elicit the biological or medical response of a tissue, system, animal or human that is being sought by the researcher, veterinarian, medical doctor or other clinician.

The term "composition" as used herein is intended to encompass a product comprising the specified ingredients in the specified amounts, as well as any product which results, directly or indirectly, from combination of the specified ingredients in the specified amounts.

By "pharmaceutically acceptable" it is meant that the carrier, diluent or excipient must be compatible with the other ingredients of the formulation and not be deleterious to the recipient thereof.

The terms "administration of a compound" and "administering a compound" should be understood to mean providing a compound of the invention or a prodrug of a compound of the invention to the individual in need of treatment.

By the term "modulating a function mediated by the androgen receptor in a tissue selective manner" it is meant modulating a function mediated by the androgen receptor selectively (or discriminately) in anabolic (bone and/or muscular) tissue (bone and muscular) in the absence of such modulation at androgenic (reproductive) tissue, such as the prostate, testis, seminal vesicles, ovary, uterus, and other sex accessory tissues. In one embodiment, the function of the androgen receptor in anabolic tissue is activated whereas the function of the androgen receptor in androgenic tissue is blocked or suppressed. In another embodiment, the function of the androgen receptor in anabolic tissue is blocked or suppressed whereas the function of the androgen receptor in androgenic tissue is activated.

The administration of a compound of structural formula I in order to practice the present methods of therapy is carried out by administering an effective amount of the compound of structural formula I to the patient in need of such treatment or prophylaxis. The need for a prophylactic administration according to the methods of the present invention is determined via the use of well-known risk factors. The effective amount of an individual compound is determined, in the final analysis, by the physician in charge of the case, but depends on factors such as the exact disease to be treated, the severity of the disease and other diseases or conditions from which the patient suffers, the chosen route of administration, other drugs and treatments which the patient can concomitantly require, and other factors in the physician's judgment.

If formulated as a fixed dose, such combination products employ the compounds of this invention within the dosage range described below and the other pharmaceutically active agent(s) within its approved dosage range. Compounds of the instant invention can alternatively be used sequentially with known pharmaceutically acceptable agent(s) when a combination formulation is inappropriate.

Generally, the daily dosage of a compound of structural formula I can be varied over a wide range from about 0.01 to about 1000 mg per adult human per day. For example, dosages range from about 0.1 to about 200 mg/day. For oral administration, the compositions can be provided in the form of tablets containing from about 0.01 to about 1000 mg, such as for example, 0.01, 0.05, 0.1, 0.5, 1.0, 2.5, 3.0, 5.0, 6.0, 10.0, 15.0, 25.0, 50.0, 75, 100, 125, 150, 175, 180, 200, 225, and 500 milligrams of the active ingredient for the symptomatic adjustment of the dosage to the mammal to be treated.

The dose can be administered in a single daily dose or the total daily dosage can be administered in divided doses of two, three or four times daily. Furthermore, based on the properties of the individual compound selected for administration, the dose can be administered less frequently, e.g., weekly, twice weekly, monthly, etc. The unit dosage will, of course, be correspondingly larger for the less frequent administration.

When administered via intranasal routes, transdermal routes, by rectal or vaginal suppositories, or through an intravenous solution, the dosage administration will, of course, be continuous rather than intermittent throughout the dosage regimen.

Exemplifying the invention is a pharmaceutical composition comprising any of the compounds described above and a pharmaceutically acceptable carrier. Also exemplifying the invention is a pharmaceutical composition made by combining any of the compounds described above and a pharmaceutically acceptable carrier. An illustration of the invention is a process for making a pharmaceutical composition comprising combining any of the compounds described above and a pharmaceutically acceptable carrier.

Formulations of the tissue-selective androgen receptor modulator employed in the present method for medical use comprise a compound of structural formula I together with an acceptable carrier thereof and optionally other therapeutically active ingredients. The carrier must be pharmaceutically acceptable in the sense of being compatible with the other ingredients of the formulation and not being deleterious to the recipient subject of the formulation.

The present invention, therefore, further provides a pharmaceutical formulation comprising a compound of structural formula I together with a pharmaceutically acceptable carrier thereof. The formulations include those suitable for oral, rectal, intravaginal, intranasal, topical and parenteral (including subcutaneous, intramuscular and intravenous administration). In one embodiment, the formulations are those suitable for oral administration.

Suitable topical formulations of a compound of formula I include transdermal devices, aerosols, creams, solutions, ointments, gels, lotions, dusting powders, and the like. The topical pharmaceutical compositions containing the compounds of the present invention ordinarily include about 0.005% to about 5% by weight of the active compound in admixture with a pharmaceutically acceptable vehicle. Transdermal skin patches useful for administering the compounds of the present invention include those well known to those of ordinary skill in that art.

The formulations can be presented in a unit dosage form and can be prepared by any of the methods known in the art of pharmacy. All methods include the step of bringing the active compound in association with a carrier, which constitutes one or more ingredients. In general, the formulations are prepared by uniformly and intimately bringing the active compound in association with a liquid carrier, a waxy solid carrier or a finely divided solid carrier, and then, if needed, shaping the product into the desired dosage form.

Formulations of the present invention suitable for oral administration can be presented as discrete units such as capsules, cachets, tablets or lozenges, each containing a predetermined amount of

the active compound; as a powder or granules; or a suspension or solution in an aqueous liquid or non-aqueous liquid, e.g., a syrup, an elixir, or an emulsion.

A tablet can be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets can be prepared by compressing in a suitable machine the active compound in a free flowing form, e.g., a powder or granules, optionally mixed with accessory ingredients, e.g., binders, lubricants, inert diluents, disintegrating agents or coloring agents. Molded tablets can be made by molding in a suitable machine a mixture of the active compound, preferably in powdered form, with a suitable carrier. Suitable binders include, without limitation, starch, gelatin, natural sugars such as glucose or beta-lactose, corn sweeteners, natural and synthetic gums such as acacia, tragacanth or sodium alginate, carboxymethyl-cellulose, polyethylene glycol, waxes and the like. Non-limiting representative lubricants used in these dosage forms include sodium oleate, sodium stearate, magnesium stearate, sodium benzoate, sodium acetate, sodium chloride and the like. Disintegrators include, without limitation, starch, methyl cellulose, agar, bentonite, xanthan gum and the like.

Oral liquid forms, such as syrups or suspensions in suitably flavored suspending or dispersing agents such as the synthetic and natural gums, for example, tragacanth, acacia, methyl cellulose and the like, can be made by adding the active compound to the solution or suspension. Additional dispersing agents which can be employed include glycerin and the like.

Formulations for vaginal or rectal administration can be presented as a suppository with a conventional carrier, i.e., a base that is nontoxic and nonirritating to mucous membranes, compatible with a compound of structural formula I, and is stable in storage and does not bind or interfere with the release of the compound of structural formula I. Suitable bases include: cocoa butter (theobroma oil), polyethylene glycols (such as carbowax and polyglycols), glycol-surfactant combinations, polyoxyl 40 stearate, polyoxyethylene sorbitan fatty acid esters (such as Tween, Myrj, and Arlacel), glycerinated gelatin, and hydrogenated vegetable oils. When glycerinated gelatin suppositories are used, a preservative such as methylparaben or propylparaben can be employed.

Topical preparations containing the active drug component can be admixed with a variety of carrier materials well known in the art, such as, e.g., alcohols, aloe vera gel, allantoin, glycerine, vitamin A and E oils, mineral oil, PPG2 myristyl propionate, and the like, to form, e.g., alcoholic solutions, topical cleansers, cleansing creams, skin gels, skin lotions, and shampoos in cream or gel formulations.

The compounds of the present invention can also be administered in the form of liposome delivery systems, such as small unilamellar vesicles, large unilamellar vesicles and

multilamellar vesicles. Liposomes can be formed from a variety of phospholipids, such as cholesterol, stearylamine or phosphatidylcholines.

Compounds of the present invention can also be delivered by the use of monoclonal antibodies as individual carriers to which the compound molecules are coupled. The compounds of the present invention can also be coupled with soluble polymers as targetable drug carriers. Such polymers can include polyvinyl-pyrrolidone, pyran copolymer, polyhydroxypropylmethacrylamide-phenol, polyhydroxy-ethylaspartamidephenol, or polyethylene-oxide polylysine substituted with palmitoyl residues. Furthermore, the compounds of the present invention can be coupled to a class of biodegradable polymers useful in achieving controlled release of a drug, for example, polylactic acid, polyepsilon caprolactone, polyhydroxy butyric acid, polyorthoesters, polyacetals, polydihydropyrans, polycyanoacrylates and cross-linked or amphipathic block copolymers of hydrogels.

Formulations suitable for parenteral administration include formulations that comprise a sterile aqueous preparation of the active compound which can be isotonic with the blood of the recipient. Such formulations suitably comprise a solution or suspension of a compound that is isotonic with the blood of the recipient subject. Such formulations can contain distilled water, 5% dextrose in distilled water or saline and the active compound. Often it is useful to employ a pharmaceutically and pharmacologically acceptable acid addition salt of the active compound that has appropriate solubility for the solvents employed. Useful formulations also comprise concentrated solutions or solids comprising the active compound which on dilution with an appropriate solvent give a solution suitable for parenteral administration.

The pharmaceutical composition and method of the present invention can further comprise other therapeutically active compounds usually applied in the treatment of the above mentioned conditions, including osteoporosis, periodontal disease, bone fracture, bone damage following bone reconstructive surgery, sarcopenia, frailty, aging skin, male hypogonadism, post-menopausal symptoms in women, atherosclerosis, hypercholesterolemia, hyperlipidemia, hematopoietic disorders, such as for example, aplastic anemia, pancreatic cancer, Alzheimer's disease, inflammatory arthritis, and joint repair.

For the treatment and prevention of osteoporosis, the compounds of the present invention can be administered in combination with at least one bone-strengthening agent selected from antiresorptive agents, osteoanabolic agents, and other agents beneficial for the skeleton through mechanisms which are not precisely defined, such as calcium supplements, flavonoids, and vitamin D analogs. The conditions of periodontal disease, bone fracture, and bone damage following bone reconstructive surgery can also benefit from these combined treatments. For example, the compounds of the instant invention can be effectively administered in combination with effective amounts of other

agents such as estrogens, bisphosphonates, SERMs, cathepsin K inhibitors, αvβ3 integrin receptor antagonists, vacuolar ATPase inhibitors, the polypeptide osteoprotegerin, antagonists of VEGF, thiazolidinediones, calcitonin, protein kinase inhibitors, parathyroid hormone (PTH) and analogs, calcium receptor antagonists, growth hormone secretagogues, growth hormone releasing hormone, insulin-like growth factor, bone morphogenetic protein (BMP), inhibitors of BMP antagonism, prostaglandin derivatives, fibroblast growth factors, vitamin D and derivatives thereof, vitamin K and derivatives thereof, soy isoflavones, calcium salts, and fluoride salts. The conditions of periodontal disease, bone fracture, and bone damage following bone reconstructive surgery can also benefit from these combined treatments.

In one embodiment of the present invention, a compound of the instant invention can be effectively administered in combination with an effective amount of at least one bone-strengthening agent chosen from estrogen, and estrogen derivatives, alone or in combination with progestin or progestin derivatives; bisphosphonates; antiestrogens or selective estrogen receptor modulators; αvβ3 integrin receptor antagonists; cathepsin K inhibitors; osteoclast vacuolar ATPase inhibitors; calcitonin; and osteoprotegerin.

In the treatment of osteoporosis, the activity of the compounds of the present invention are distinct from that of the anti-resorptive agents: estrogens, bisphosphonates, SERMs, calcitonin, cathepsin K inhibitors, vacuolar ATPase inhibitors, agents interfering with the RANK/RANKL/Osteoprotegerin pathway, p38 inhibitors or any other inhibitors of osteoclast generation or osteoclast activation. Rather than inhibiting bone resorption, the compounds of structural formula I aid in the stimulation of bone formation, acting, for example, on cortical bone, which is responsible for a significant part of bone strength. The thickening of cortical bone substantially contributes to a reduction in fracture risk, especially fractures of the hip. The combination of the tissue-SARMs of structural formula I with anti-resorptive agents such as for example estrogen or estrogen derivatives, bisphosphonates, antiestrogens, SERMs, calcitonin, αvβ3 integrin receptor antagonists, HMG-CoA reductase inhibitors, vacuolar ATPase inhibitors, and cathepsin K inhibitors is particularly useful due to the complementary effect of the bone anabolic and antiresorptive actions.

Non-limiting representatives of estrogen and estrogen derivatives include steroidal compounds having estrogenic activity such as, for example, 17β-estradiol, estrone, conjugated estrogen (PREMARIN®), equine estrogen, 17β-ethynyl estradiol, and the like. The estrogen or estrogen derivative can be employed alone or in combination with a progestin or progestin derivative. Nonlimiting examples of progestin derivatives are norethindrone and medroxy-progesterone acetate.

Non-limiting examples of bisphosphonate compounds which can also be employed in combination with a compound of the present invention include:

(a) alendronate (also known as alendronic acid, 4-amino-1-hydroxybutylidene-1,1-bisphosphonic acid, alendronate sodium, alendronate monosodium trihydrate or 4-amino-1-hydroxybutylidene-1,1-bisphosphonic acid monosodium trihydrate. Alendronate is described in U.S. Patents 4,922,007, to Kieczykowski et al., issued May 1, 1990; 5,019,651, to Kieczykowski, issued May 28, 1991; 5,510,517, to Dauer et al., issued April 23, 1996; 5,648,491, to Dauer et al., issued July 15, 1997;

(b) [(cycloheptylamino)-methylene]-bis-phosphonate (incadronate), which is described in U.S. Patent 4,970,335, to Isomura et al., issued November 13, 1990;

(c) (dichloromethylene)-bis-phosphonic acid (clodronic acid) and the disodium salt (clodronate), which are described in Belgium Patent 672,205 (1966) and *J. Org. Chem 32*, 4111 (1967);

(d) [1-hydroxy-3-(1-pyrrolidinyl)-propylidene]-bis-phosphonate (EB-1053);

(e) (1-hydroxyethylidene)-bis-phosphonate (etidronate);

(f) [1-hydroxy-3-(methylpentylamino)propylidene]-bis-phosphonate (ibandronate), which is described in U.S. Patent No. 4,927,814, issued May 22, 1990;

(g) (6-amino-1-hydroxyhexylidene)-bis-phosphonate (neridronate);

(h) [3-(dimethylamino)-1-hydroxypropylidene]-bis-phosphonate (olpadronate);

(i) (3-amino-1-hydroxypropylidene)-bis-phosphonate (pamidronate);

(j) [2-(2-pyridinyl)ethylidene]-bis-phosphonate (piridronate), which is described in U.S. Patent No. 4,761,406;

(k) [1-hydroxy-2-(3-pyridinyl)-ethylidene]-bis-phosphonate (risedronate);

(l) {[(4-chlorophenyl)thio]methylene}-bis-phosphonate (tiludronate), which is described in U.S. Patent 4,876,248, to Breliere et al., October 24, 1989;

(m) [1-hydroxy-2-(1H-imidazol-1-yl)ethylidene]-bis-phosphonate (zoledronate); and

(n) [1-hydroxy-2-imidazopyridin-(1,2-a)-3-ylethylidene]-bis-phosphonate (minodronate).

In one embodiment of the methods and compositions of the present invention, the bisphosphonate is chosen from alendronate, clodronate, etidronate, ibandronate, incadronate, minodronate, neridronate, olpadronate, pamidronate, piridronate, risedronate, tiludronate, zoledronate, pharmaceutically acceptable salts of these bisphosphonates, and mixtures thereof. In one variant, the bisphosphonate is selected from alendronate, risedronate, zoledronate, ibandronate, tiludronate, and clodronate. In a subclass of this class, the bisphosphonate is alendronate, pharmaceutically acceptable salts and hydrates thereof, and mixtures thereof. A particular pharmaceutically acceptable salt of alendronate is alendronate monosodium. Pharmaceutically acceptable hydrates of alendronate monosodium include the monohydrate and the trihydrate. A particular pharmaceutically acceptable salt

of risedronate is risedronate monosodium. Pharmaceutically acceptable hydrates of risedronate monosodium include the hemi-pentahydrate.

Still further, antiestrogenic compounds such as raloxifene (see, e.g., U.S. Patent No. 5,393,763), clomiphene, zuclomiphene, enclomiphene, nafoxidene, CI-680, CI-628, CN-55,945-27, Mer-25, U-11,555A, U-100A, and salts thereof, and the like (see, e.g., U.S. Patent Nos. 4,729,999 and 4,894,373) can be employed in combination with a compound of structural formula I in the methods and compositions of the present invention. These agents are also known as SERMs, or selective estrogen receptor modulators, agents known in the art to prevent bone loss by inhibiting bone resorption via pathways believed to be similar to those of estrogens.

Non-limiting representatives of SERMs include, for example, tamoxifen, raloxifene, lasofoxifene, toremifene, azorxifene, EM-800, EM-652, TSE 424, clomiphene, droloxifene, idoxifene, and levormeloxifene [Goldstein, et al., "A pharmacological review of selective estrogen receptor modulators," Human Reproduction Update, 6: 212-224 (2000); Lufkin, et al., Rheumatic Disease Clinics of North America, 27: 163-185 (2001), and "Targeting the Estrogen Receptor with SERMs," Ann. Rep. Med. Chem. 36: 149-158 (2001)].

αvβ3 Integrin receptor antagonists suppress bone resorption and can be employed in combination with the SARMs of structural formula I for the treatment of bone disorders including osteoporosis. Peptidyl as well as peptidomimetic antagonists of the αvβ3 integrin receptor have been described both in the scientific and patent literature. For example, reference is made to W.J. Hoekstra and B.L. Poulter, Curr. Med. Chem. 5: 195-204 (1998) and references cited therein; WO 95/32710; WO 95/37655; WO 97/01540; WO 97/37655; WO 98/08840; WO 98/18460; WO 98/18461; WO 98/25892; WO 98/31359; WO 98/30542; WO 99/15506; WO 99/15507; WO 00/03973; EP 853084; EP 854140; EP 854145; US Patent Nos. 5,204,350; 5,217,994; 5,639,754; 5,741,796; 5,780,426; 5,929,120; 5,952,341; 6,017,925; and 6,048,861.

Other αvβ3 antagonists are described in R.M. Keenan et al., J. Med. Chem. 40: 2289-2292 (1997); R.M. Keenan et al., Bioorg. Med. Chem. Lett. 8: 3165-3170 (1998); and R.M. Keenan et al., Bioorg. Med. Chem. Lett. 8: 3171-3176 (1998).

Other non-limiting representative examples of published patent and patent applications that describe various αvβ3 integrin receptor antagonists include: those comprising benzazepine, benzodiazepine and benzocycloheptene—PCT Patent Application Nos. WO 96/00574, WO 96/00730, WO 96/06087, WO 96/26190, WO 97/24119, WO 97/24122, WO 97/24124, WO 98/14192, WO 98/15278, WO 99/05107, WO 99/06049, WO 99/15170, WO 99/15178, WO 97/34865,WO 99/15506, and U.S. Patent No. 6,159,964; those comprising dibenzpcyclopheptene, and dibenzoxapine –PCT Patent Application Nos. WO 97/01540, WO 98/30542, WO 99/11626, WO 99/15508, and U.S. Patent

Nos. 6,008,213 and 6,069,158; those having a phenol constraint—PCT Patent Application Nos. WO 98/00395, WO 99/32457, WO 99/37621, WO 99/44994, WO 99/45927,WO 99/52872, WO 99/52879, WO 99/52896, WO 00/06169, European Patent Nos. EP 0 820,988, EP 0 820,991, and U.S. Patent Nos. 5,741,796, 5773,644, 5,773,646, 5,843,906, 5,852,210, 5,929,120, 5,952,281, 6,028,223 and 6,040,311; those having a monocyclic ring constraint –PCT Patent Application Nos. WO 99/26945, WO 99/30709, WO 99/30713, WO 99/31099, WO 99/59992, WO 00/00486, WO 00/09503, European Patent Nos. EP 0 796,855, EP 0 928,790, EP 0 928,793, and U.S. Patent Nos. 5,710,159, 5,723,480, 5,981,546, 6,017,926, and 6,066,648; and those having a bicyclic ring constraint –PCT Patent Application Nos. WO 98/23608, WO 98/35949, and WO 99/33798, European Patent No. EP 0 853,084, and U.S. Patent Nos. 5,760,028, 5,919,792, and 5,925,655.

Cathepsin K, formerly known as cathepsin O2, is a cysteine protease and is described in PCT International Application Publication No. WO 96/13523; U.S. Patent Nos. 5,501,969 and 5,736,357. Cysteine proteases, specifically cathepsins, are linked to a number of disease conditions, such as tumor metastasis, inflammation, arthritis, and bone remodeling. At acidic pH's, cathepsins can degrade type-I collagen. Cathepsin protease inhibitors can inhibit osteoclastic bone resorption by inhibiting the degradation of collagen fibers and are thus useful in the treatment of bone resorption diseases, such as osteoporosis. Non-limiting examples of cathespin K inhibitors can be found in PCT International Publications WO 01/49288 and WO 01/77073.

Members of the class of HMG-CoA reductase inhibitors, known as the "statins," have been found to trigger the growth of new bone, replacing bone mass lost as a result of osteoporosis (see The Wall Street Journal, Friday, December 3, 1999, page B1). Therefore, the statins hold promise for the treatment of bone resorption. Examples of HMG-CoA reductase inhibitors include statins in their lactonized or dihydroxy open acid forms and pharmaceutically acceptable salts and esters thereof, including but not limited to lovastatin (see US Patent No. 4,342,767); simvastatin (see US Patent No. 4,444,784); dihydroxy open-acid simvastatin, particularly the ammonium or calcium salts thereof; pravastatin, particularly the sodium salt thereof (see US Patent No. 4,346,227); fluvastatin, particularly the sodium salt thereof (see US Patent No. 5,354,772); atorvastatin, particularly the calcium salt thereof (see US Patent No. 5,273,995); cerivastatin, particularly the sodium salt thereof (see US Patent No. 5,177,080), rosuvastatin, also known as ZD-4522 (see US Patent No. 5,260,440) and pitavastatin, also referred to as NK-104, itavastatin, or nisvastatin (see PCT international application publication number WO 97/23200).

Osteoclast vacuolar ATPase inhibitors, also called proton pump inhibitors, can be employed together with the SARMs of structural formula I. The proton ATPase which is found on the apical membrane of the osteoclast has been reported to play a significant role in the bone resorption

process. Therefore, this proton pump represents an attractive target for the design of inhibitors of bone resorption which are potentially useful for the treatment and prevention of osteoporosis and related metabolic diseases [see C. Farina et al., DDT, 4: 163-172 (1999)].

The angiogenic factor VEGF has been shown to stimulate the bone-resorbing activity of isolated mature rabbit osteoclasts via binding to its receptors on osteoclasts [see M. Nakagawa et al., FEBS Letters, 473: 161-164 (2000)]. Therefore, the development of antagonists of VEGF binding to osteoclast receptors, such as KDR/Flk-1 and Flt-1, can provide yet a further approach to the treatment or prevention of bone resorption.

Activators of the peroxisome proliferator-activated receptor-γ (PPARγ), such as the thiazolidinediones (TZD's), inhibit osteoclast-like cell formation and bone resorption *in vitro*. Results reported by R. Okazaki et al. in Endocrinology, 140: 5060-5065 (1999) point to a local mechanism on bone marrow cells as well as a systemic one on glucose metabolism. Nonlimiting examples of PPARγ, activators include the glitazones, such as troglitazone, pioglitazone, rosiglitazone, and BRL 49653.

Calcitonin can also be employed together with the SARMs of structural formula I. Calcitonin is preferentially employed as salmon nasal spray (Azra et al., Calcitonin. 1996. In: J. P. Bilezikian, et al., Ed., Principles of Bone Biology, San Diego: Academic Press; and Silverman, "Calcitonin," Rheumatic Disease Clinics of North America, 27: 187-196, 2001)

Protein kinase inhibitors can also be employed together with the SARMs of structural formula I. Kinase inhibitors include those disclosed in WO 01/17562 and are in one embodiment selected from inhibitors of p38. Non-limiting examples of p38 inhibitors useful in the present invention include SB 203580 [Badger et al., J. Pharmacol. Exp. Ther., 279: 1453-1461 (1996)].

Osteoanabolic agents are those agents that are known to build bone by increasing the production of the bone protein matrix. Such osteoanabolic agents include, for example, parathyroid hormone (PTH) and fragments thereof, such as naturally occurring PTH (1-84), PTH (1-34), analogs thereof, native or with substitutions and particularly parathyroid hormone subcutaneous injection. PTH has been found to increase the activity of osteoblasts, the cells that form bone, thereby promoting the synthesis of new bone (Modern Drug Discovery, Vol. 3, No. 8, 2000). An injectable recombinant form of human PTH, Forteo (teriparatide), has received regulatory approval in the U.S. for the treatment of osteoporosis.

Also useful in combination with the SARMs of the present invention are calcium receptor antagonists which induce the secretion of PTH as described by Gowen et al., J. Clin. Invest. 105: 1595-604 (2000).

Additional osteoanabolic agents include growth hormone secretagogues, growth hormone, growth hormone releasing hormone and the like can be employed with the compounds

according to structural formula I for the treatment of osteoporosis. Representative growth hormone secretagogues are disclosed in U.S. Patent Nos. 3,239,345, 4,036,979, 4,411,890, 5,206,235, 5,283,241, 5,284,841, 5,310,737, 5,317,017, 5,374,721, 5,430,144, 5,434,261, 5,438,136, 5,494,919, 5,494,920, 5,492,916 and 5,536,716; European Patent Pub. Nos. 0,144,230 and 0,513,974; PCT Patent Pub. Nos. WO 94/07486, WO 94/08583, WO 94/11012; WO 94/13696, WO 94/19367, WO 95/03289, WO 95/03290, WO 95/09633, WO 95/11029, WO 95/12598, WO 95/13069, WO 95/14666, WO 95/16675, WO 95/16692, WO 95/17422, WO 95/17423, WO 95/34311, and WO 96/02530; articles, Science, 260, 1640-1643 (June 11, 1993); Ann. Rep. Med. Chem., 28: 177-186 (1993); Bioorg. Med. Chem. Lett., 4: 2709-2714 (1994); and Proc. Natl. Acad. Sci. USA, 92: 7001-7005 (1995).

Insulin-like growth factor (IGF) can also be employed together with the SARMs of structural formula I. Insulin-like growth factors can be selected from Insulin-like Growth Factor I, alone or in combination with IGF binding protein 3 and IGF II [See Johannson and Rosen, "The IGFs as potential therapy for metabolic bone diseases," 1996, In: Bilezikian, et al., Ed., Principles of Bone Biology, San Diego: Academic Press; and Ghiron et al., J. Bone Miner. Res. 10: 1844-1852 (1995)].

Bone morphogenetic protein (BMP) can also be employed together with the SARMs of structural formula I. Bone morphogenetic protein includes BMP 2, 3, 5, 6, 7, as well as related molecules TGF beta and GDF 5 [Rosen et al., "Bone morphogenetic proteins," 1996. In: J. P. Bilezikian, et al., Ed., Principles of Bone Biology, San Diego: Academic Press; and Wang EA, Trends Biotechnol., 11: 379-383 (1993)].

Inhibitors of BMP antagonism can also be employed together with the SARMs of structural formula I. In one embodiment, BMP antagonist inhibitors are chosen from inhibitors of the BMP antagonists SOST, noggin, chordin, gremlin, and dan [see Massague and Chen, "Controlling TGF-beta signaling," Genes Dev., 14: 627-644, 2000; Aspenberg et al., J. Bone Miner. Res. 16: 497-500, 2001; and Brunkow et al., Am. J. Hum. Genet. 68: 577-89 (2001)].

The tissue-selective androgen receptor modulators of the present invention can also be combined with the polypeptide osteoprotegerin for the treatment of conditions associated with bone loss, such as osteoporosis. The osteoprotegerin can be selected from mammalian osteoprotegerin and human osteoprotegerin. The polypeptide osteoprotegerin, a member of the tumor necrosis factor receptor super-family, is useful to treat bone diseases characterized by increased bone loss, such as osteoporosis. Reference is made to U.S. Patent No. 6,288,032.

Prostaglandin derivatives can also be employed together with the SARMs of structural formula I. Non-limiting representatives of prostaglandin derivatives are selected from agonists of prostaglandin receptors EP1, EP2, EP4, FP, IP and derivatives thereof [Pilbeam et al., "Prostaglandins

and bone metabolism," 1996. In: Bilezikian, et al. Ed. Principles of Bone Biology, San Diego: Academic Press; Weinreb et al., Bone, 28: 275-281 (2001)].

Fibroblast growth factors can also be employed together with the SARMs of structural formula I. Fibroblast growth factors include aFGF, bFGF and related peptides with FGF activity [Hurley Florkiewicz, "Fibroblast growth factor and vascular endothelial growth factor families," 1996. In: J. P. Bilezikian, et al., Ed. Principles of Bone Biology, San Diego: Academic Press].

In addition to bone resorption inhibitors and osteoanabolic agents, there are also other agents known to be beneficial for the skeleton through mechanisms which are not precisely defined. These agents can also be favorably combined with the SARMs of structural formula I.

Vitamin D, vitamin D derivatives and analogs can also be employed together with the SARMs of structural formula I. Vitamin D and vitamin D derivatives include, for example, D_3 (cholecaciferol), D_2 (ergocalciferol), 25-OH-vitamin D_3, 1α,25$(OH)_2$ vitamin D_3, 1α-OH-vitamin D_3, 1α-OH-vitamin D_2, dihydrotachysterol, 26,27-F6-1α,25$(OH)_2$ vitamin D_3, 19-nor-1α,25$(OH)_2$ vitamin D_3, 22-oxacalcitriol, calcipotriol, 1α,25$(OH)_2$-16-ene-23-yne-vitamin D_3 (Ro 23-7553), EB1089, 20-epi-1α,25$(OH)_2$ vitamin D_3, KH1060, ED71, 1α,24(S)-$(OH)_2$ vitamin D_3, 1α,24(R)-$(OH)_2$ vitamin D_3 [See, Jones G., "Pharmacological mechanisms of therapeutics: vitamin D and analogs," 1996. In: J. P. Bilezikian, et al. Ed. Principles of Bone Biology, San Diego: Academic Press].

Vitamin K and Vitamin K derivatives can also be employed together with the SARMs of structural formula I. Vitamin K and vitamin K derivatives include menatetrenone (vitamin K2) [see Shiraki et al., J. Bone Miner. Res., 15: 515-521 (2000)].

Soy isoflavones, including ipriflavone, can be employed together with the SARMs of structural formula I.

Fluoride salts, including sodium fluoride (NaF) and monosodium fluorophosphate (MFP), can also be employed together with the SARMs of structural formula I. Dietary calcium supplements can also be employed together with the SARMs of structural formula I. Dietary calcium supplements include calcium carbonate, calcium citrate, and natural calcium salts (Heaney. Calcium. 1996. In: J. P. Bilezikian, et al., Ed., Principles of Bone Biology, San Diego: Academic Press).

Daily dosage ranges for bone resorption inhibitors, osteoanabolic agents and other agents which can be used to benefit the skeleton when used in combination with a compound of structural formula I are those which are known in the art. In such combinations, generally the daily dosage range for the SARMs of structural formula I ranges from about 0.01 to about 1000 mg per adult human per day, such as for example, from about 0.1 to about 200 mg/day. However, adjustments to decrease the dose of each agent can be made due to the increased efficacy of the combined agent.

In particular, when a bisphosphonate is employed, dosages from about 2.5 to about 100 mg/day (measured as the free bisphosphonic acid) are appropriate for treatment, such as for example ranging from 5 to 20 mg/day, or about 10 mg/day. Prophylactically, doses of about 2.5 to about 10 mg/day and especially about 5 mg/day should be employed. For reduction in side-effects, it can be desirable to administer the combination of a compound of structural formula I and the bisphosphonate once a week. For once weekly administration, doses ranging from about 15 mg to about 700 mg per week of bisphosphonate and from about 0.07 to about 7000 mg of a compound of structural formula I can be employed, either separately, or in a combined dosage form. A compound of structural formula I can be favorably administered in a controlled-release delivery device, particularly for once weekly administration.

For the treatment of atherosclerosis, hypercholesterolemia, and hyperlipidemia, the compounds of structural formula I can be effectively administered in combination with one or more additional active agents. The additional active agent or agents can be chosen from lipid-altering compounds such as HMG-CoA reductase inhibitors, agents having other pharmaceutical activities, and agents that have both lipid-altering effects and other pharmaceutical activities. Non-limiting examples of HMG-CoA reductase inhibitors include statins in their lactonized or dihydroxy open acid forms and pharmaceutically acceptable salts and esters thereof, including but not limited to lovastatin (see US Patent No. 4,342,767); simvastatin (see US Patent No. 4,444,784); dihydroxy open-acid simvastatin, particularly the ammonium or calcium salts thereof; pravastatin, particularly the sodium salt thereof (see US Patent No. 4,346,227); fluvastatin, particularly the sodium salt thereof (see US Patent No. 5,354,772); atorvastatin, particularly the calcium salt thereof (see US Patent No. 5,273,995); cerivastatin, particularly the sodium salt thereof (see US Patent No. 5,177,080), and nisvastatin, also referred to as NK-104 (see PCT international application publication number WO 97/23200).

Additional active agents which can be employed in combination with a compound of structural formula I include, but are not limited to, HMG-CoA synthase inhibitors; squalene epoxidase inhibitors; squalene synthetase inhibitors (also known as squalene synthase inhibitors), acyl-coenzyme A: cholesterol acyltransferase (ACAT) inhibitors including selective inhibitors of ACAT-1 or ACAT-2 as well as dual inhibitors of ACAT-1 and -2; microsomal triglyceride transfer protein (MTP) inhibitors; probucol; niacin; cholesterol absorption inhibitors, such as SCH-58235, also known as ezetimibe and 1-(4-fluorophenyl)-3(R)-[3(S)-(4-fluorophenyl)-3-hydroxypropyl)]-4(S)-(4-hydroxyphenyl)-2-azetidinone, which is described in U.S. Patent Nos. 5,767,115 and 5,846,966; bile acid sequestrants; LDL (low density lipoprotein) receptor inducers; platelet aggregation inhibitors, for example glycoprotein IIb/IIIa fibrinogen receptor antagonists and aspirin; human peroxisome proliferator activated receptor gamma (PPARγ), agonists, including the compounds commonly referred to as glitazones, for example

troglitazone, pioglitazone and rosiglitazone and, including those compounds included within the structural class known as thiazolidinediones as well as those PPARγ, agonists outside the thiazolidinedione structural class; PPARα agonists, such as clofibrate, fenofibrate including micronized fenofibrate, and gemfibrozil; PPAR dual α/γ agonists; vitamin B_6 (also known as pyridoxine) and the pharmaceutically acceptable salts thereof such as the HCl salt; vitamin B_{12} (also known as cyanocobalamin); folic acid or a pharmaceutically acceptable salt or ester thereof such as the sodium salt and the methylglucamine salt; anti-oxidant vitamins such as vitamin C and E and beta carotene; beta-blockers; angiotensin II antagonists such as losartan; angiotensin converting enzyme inhibitors, such as enalapril and captopril; calcium channel blockers, such as nifedipine and diltiazem; endothelin antagonists; agents such as LXR ligands that enhance ABC1 gene expression; bisphosphonate compounds, such as alendronate sodium; and cyclooxygenase-2 inhibitors, such as rofecoxib and celecoxib, as well as other agents known to be useful in the treatment of these conditions.

Daily dosage ranges for HMG-CoA reductase inhibitors when used in combination with the compounds of structural formula I correspond to those which are known in the art. Similarly, daily dosage ranges for the HMG-CoA synthase inhibitors; squalene epoxidase inhibitors; squalene synthetase inhibitors (also known as squalene synthase inhibitors), acyl-coenzyme A: cholesterol acyltransferase (ACAT) inhibitors including selective inhibitors of ACAT-1 or ACAT-2 as well as dual inhibitors of ACAT-1 and -2; microsomal triglyceride transfer protein (MTP) inhibitors; probucol; niacin; cholesterol absorption inhibitors including ezetimibe; bile acid sequestrants; LDL (low density lipoprotein) receptor inducers; platelet aggregation inhibitors, including glycoprotein IIb/IIIa fibrinogen receptor antagonists and aspirin; human peroxisome proliferator activated receptor gamma (PPARγ) agonists; PPARα agonists; PPAR dual α/γ agonists; vitamin B_6; vitamin B_{12}; folic acid; anti-oxidant vitamins; beta-blockers; angiotensin II antagonists; angiotensin converting enzyme inhibitors; calcium channel blockers; endothelin antagonists; agents such as LXR ligands that enhance ABC1 gene expression; bisphosphonate compounds; and cyclooxygenase-2 inhibitors also correspond to those which are known in the art, although due to the combined action with the compounds of structural formula I, the dosage can be somewhat lower when administered in combination.

One embodiment of the invention is a method for affecting a bone turnover marker in a mammal comprising administering a therapeutically effective amount of a compound according to formula I. Non-limiting examples of bone turnover markers can be selected from urinary C-telopeptide degradation products of type I collagen (CTX), urinary N-telopeptide cross-links of type I collagen (NTX), osteocalcin (bone G1a protein), dual energy x-ray absorptionmetry (DXA), bone specific alkaline phosphatase (BSAP), quantitative ultrasound (QUS), and deoxypyridinoline (DPD) crosslinks.

In accordance with the method of the present invention, the individual components of the combination can be administered separately at different times during the course of therapy or concurrently in divided or single combination forms. The instant invention is therefore to be understood as embracing all such regimes of simultaneous or alternating treatment and the term "administering" is to be interpreted accordingly. It will be understood that the scope of combinations of the compounds of this invention with other agents useful for treating diseases caused by androgen deficiency or that can be ameliorated by addition of androgen.

Abbreviations Used in the Description of the Preparation of the Compounds of the Present Invention:

AcOH	Acetic acid
DHT	Dihydrotestosterone
DMAP	4-Dimethylaminopyridine
DMEM	Dulbecceo modified eagle media
DMSO	Dimethyl sulfoxide
DMF	N,N-Dimethylformamide
EA	Ethyl acetate
EDC	1-(3-Dimethylaminopropyl)3-ethylcarbodiimide HCl
EDTA	Ethylenediaminetetraacetic acid
EtOH	Ethanol
Et_3N	Triethylamine
FCS	Fetal calf serum
HEPES	(2-Hydroxyethyl)-1-piperazineethanesulfonic acid
HOAt	1-hydroxy-7-azabenzotriazole
HPLC	High-performance liquid chromatography
KHMDS	Potassium bistrimethylsilylamide
LCMS	Liquid chromotography/mass spectroscopy
LDA	Lithium diisopropylamide
LG	Leaving group
MeOH	Methanol
NBS	N-bromosuccinimide
n-Bu4NI	Tetra-n-butylammonium iodide
PMBCL	p-Methoxybenzyl chloride
p-TosCl	p-Toluenesulfonyl chloride
Rt or rt	Room temperature

TFA	Trifluoroacetic acid
TLC	Thin-layer chromatography

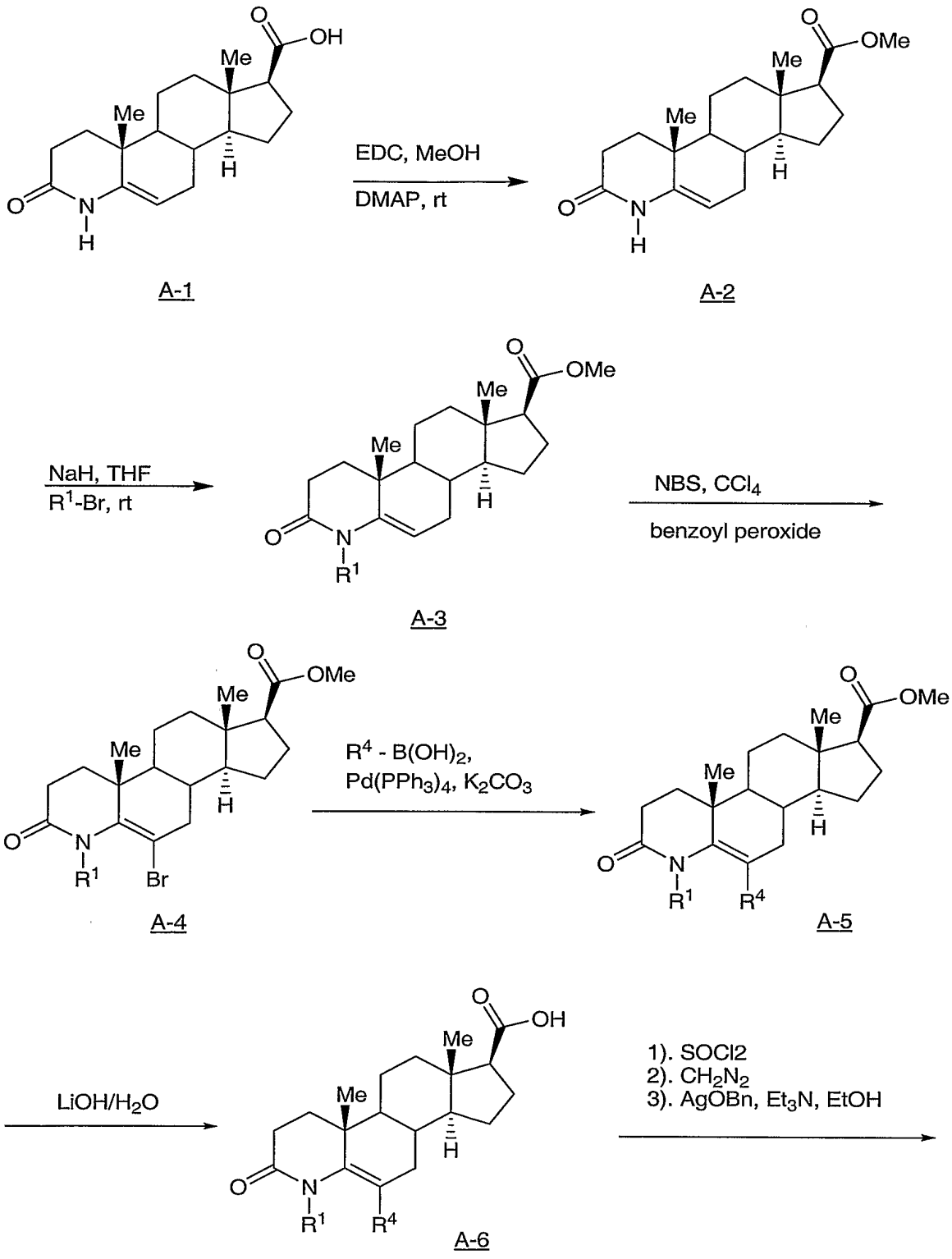
The compounds of this invention may be prepared by employing reactions as shown in the following schemes, in addition to other standard manipulations that are known in the literature or exemplified in the experimental procedures. The illustrative schemes below, therefore, are not limited by the compounds listed or by any particular substituents employed for illustrative purposes. Substituent numbering as shown in the schemes does not necessarily correlate to that used in the claims and often, for clarity, a single substituent is shown attached to the compound in place of multiple substituents which are allowed under the definitions of Formula I defined previously.

Schemes A-E provide general guidelines for making compounds of Formula I. Scheme A illustrates the various additions to the 4-azasteroidal backbone having unsaturation at the 4 and 5-position carbons, substituent R^1 at the 4-position nitrogen, and substituent R^4 at the 6-position carbon. Scheme B illustrates the hydrogenation of unsaturated 4-azasteroid. Scheme C illustrates the general synthesis of compounds of Formula I having unsaturation between carbons 1 and 2 and carbons 5-6 of the 4-azasteroidal backbone starting from compound A-5.

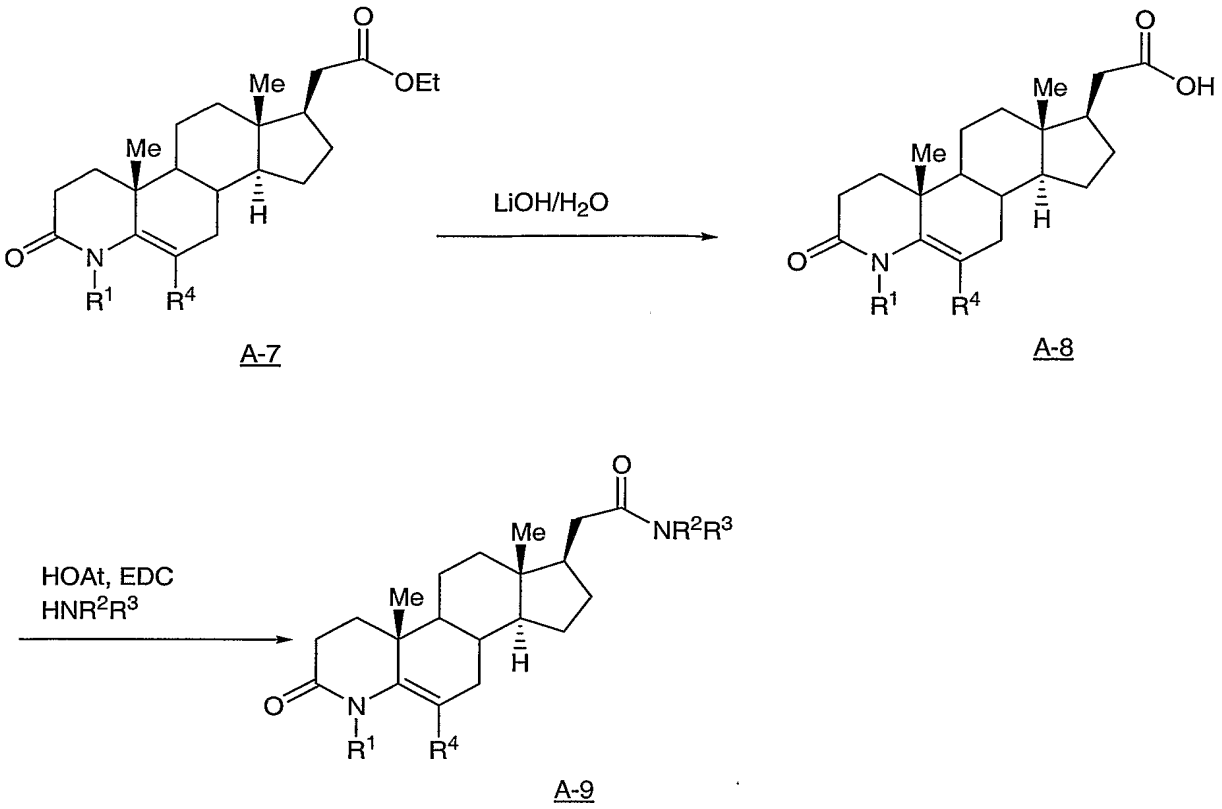
Scheme D depicts the general synthesis of compounds of Formula I having unsaturation between carbons 1 and 2 of the 4-azasteroidal backbone starting from compound A-5. Scheme E provides a general scheme for the placement of X and Y substituents of Formula I having unsaturation between carbons 1 and 2 of the 4-azasteroidal backbone. The techniques to attach X and Y shown in Scheme E utilizing leaving groups can be analogously applied to the various other illustrated unsaturated 4-azasteroids depict Schemes A, B, and C.

It should be noted that in Scheme E, the selection of the particular leaving group, LG, will of course depend upon the particular substituent class that is incorporated onto the core structure. Selection and application of leaving groups is a common practice in the synthetic organic chemical art and this information is readily known and accessible to one skilled in the art. See for example, Organic Synthesis, Smith, M, McGraw-Hill INC, 1994, New York. ISBN 0-07-048716-2.

SCHEME A



A-1 A-2 A-3 A-4 A-5 A-6

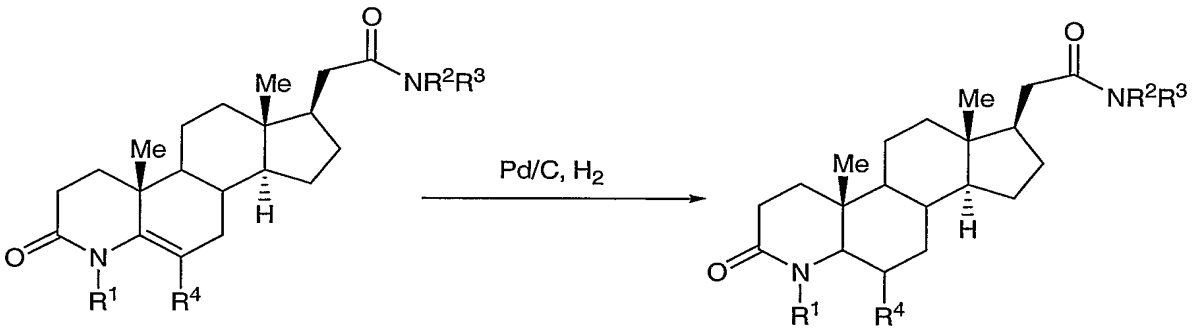

O
OEt
Me
Me
H
O
N
R1
R4
LiOH/H2O
O
OH
Me
Me
H
O
N
R1
R4
HOAt, EDC
HNR2R3
O
NR2R3
Me
Me
H
O
N
R1
R4

A-7

A-8

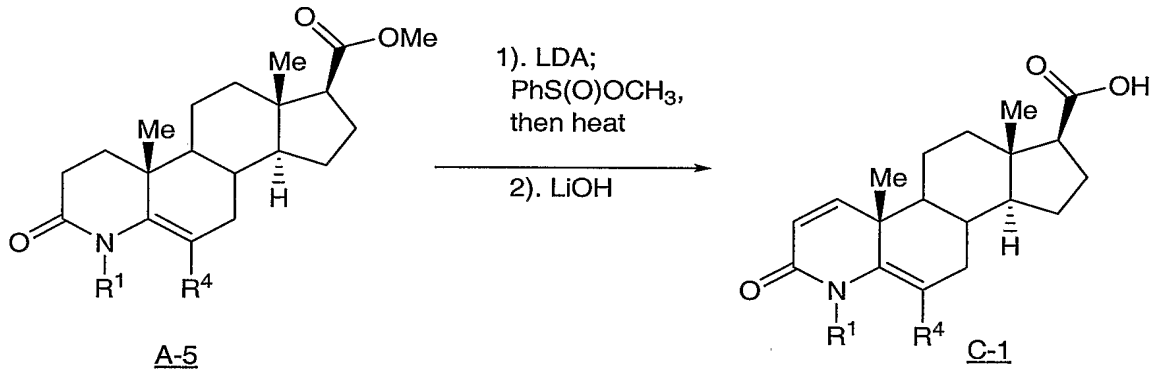
A-9

SCHEME B

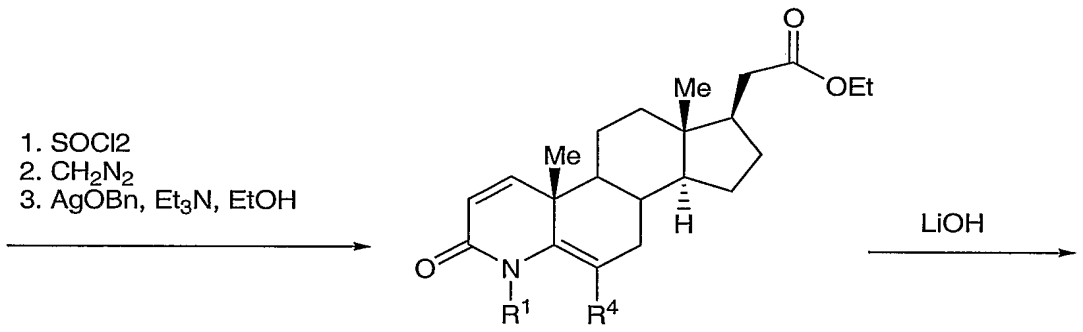


A-9 B-1

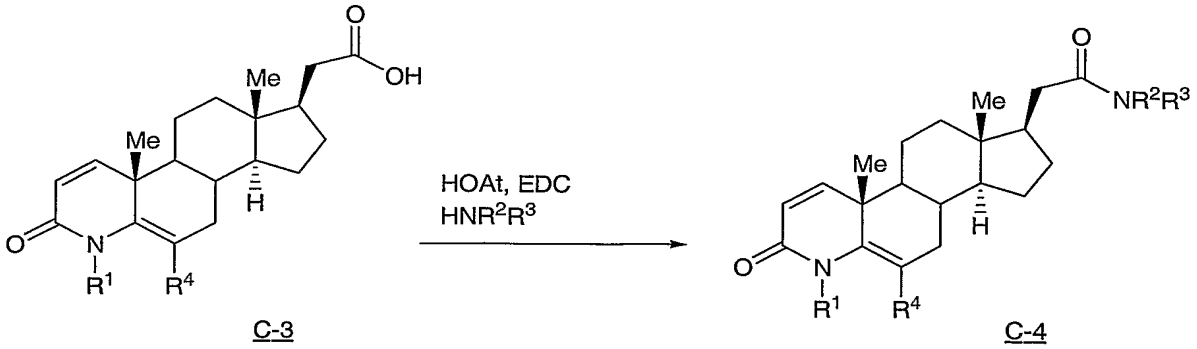
SCHEME C



A-5 C-1

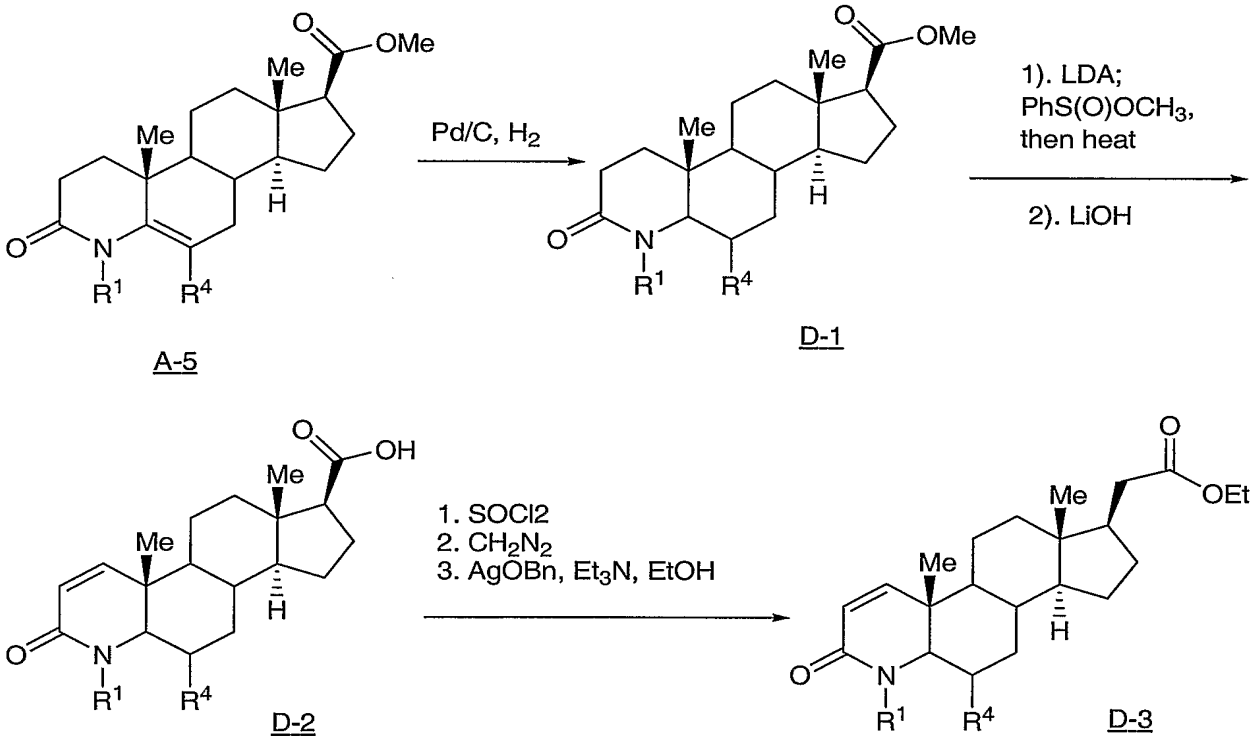


C-2

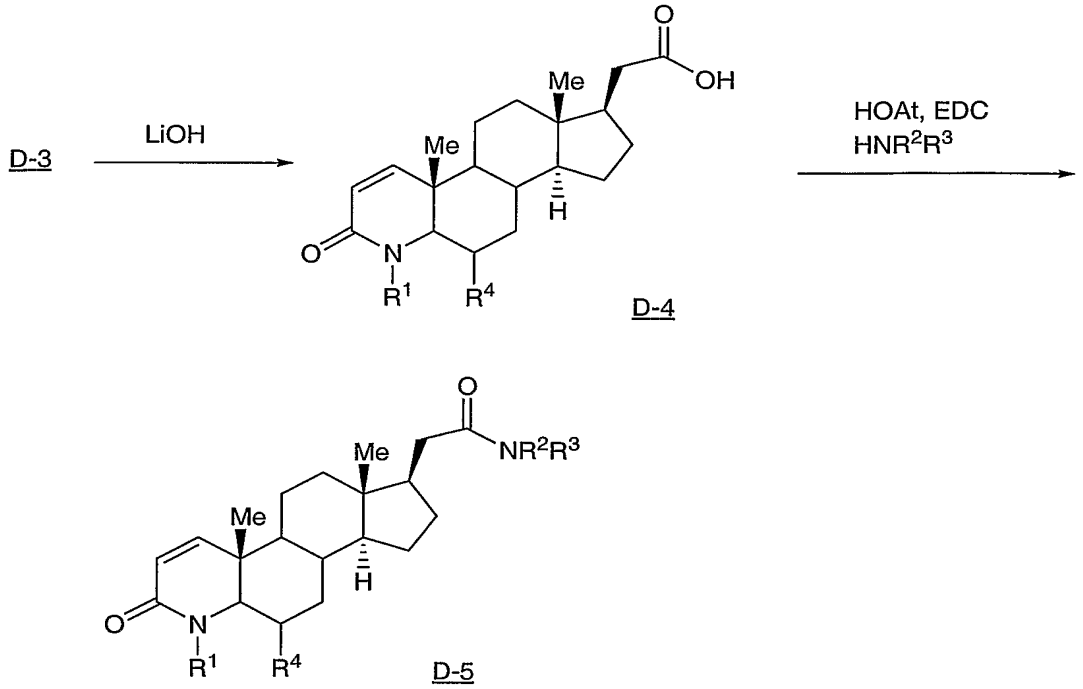


C-3 C-4

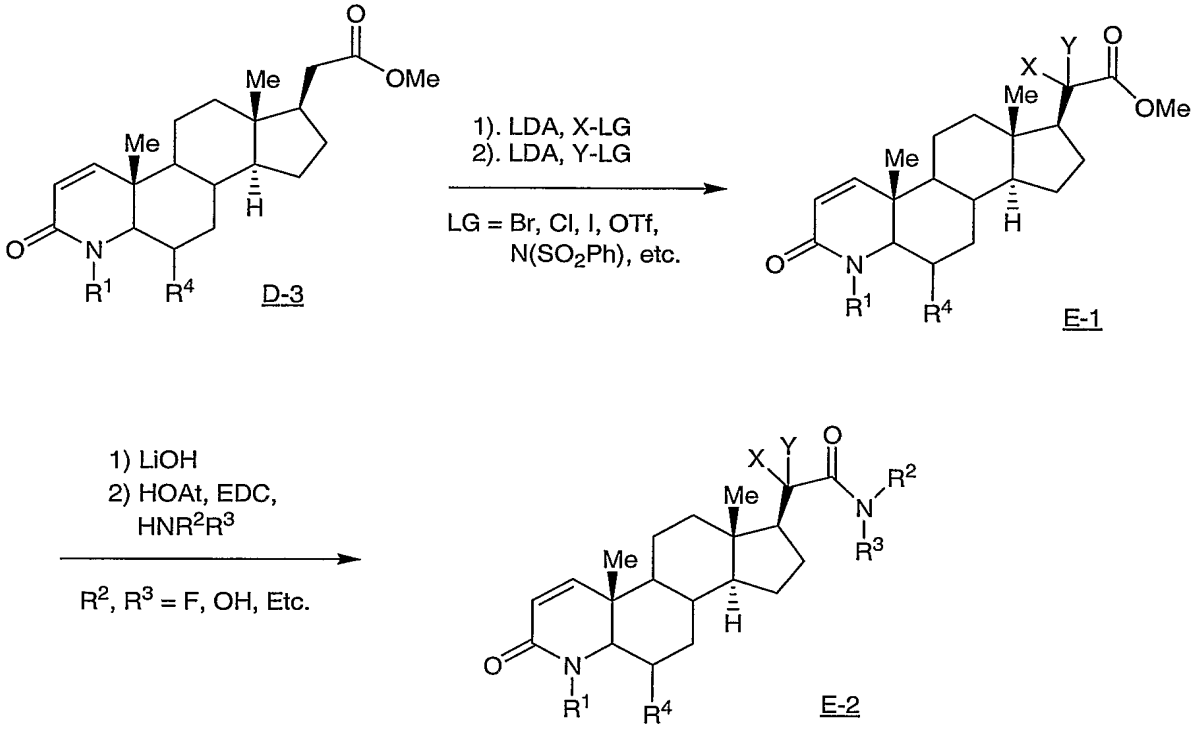
SCHEME D



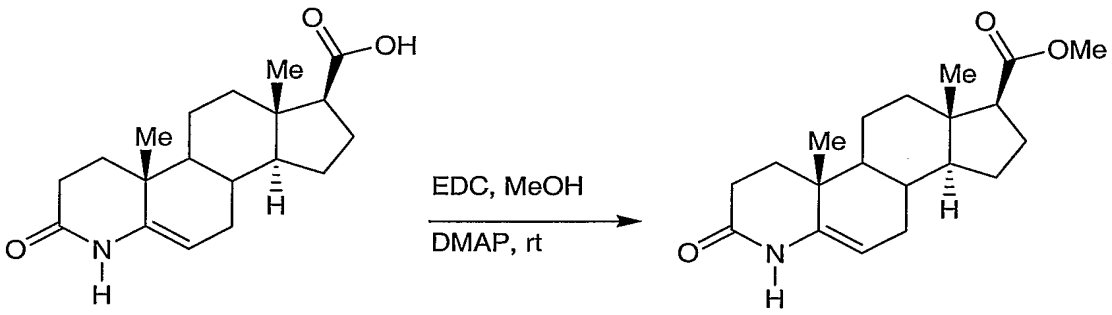
A-5 D-1 D-2 D-3


D-3
LiOH
Me
Me
O
OH
H
O
N
R1
R4
D-4
HOAt, EDC
HNR2R3
NR2R3
D-5

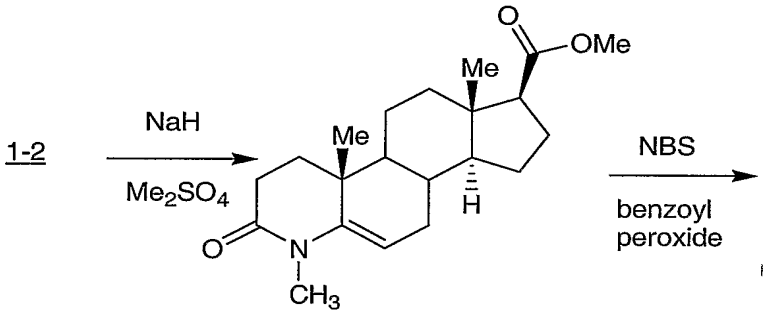
SCHEME E


D-3
OMe
1). LDA, X-LG
2). LDA, Y-LG
LG = Br, Cl, I, OTf,
N(SO2Ph), etc.
X
Y
E-1
1) LiOH
2) HOAt, EDC,
HNR2R3
R2, R3 = F, OH, Etc.
R2
R3
E-2

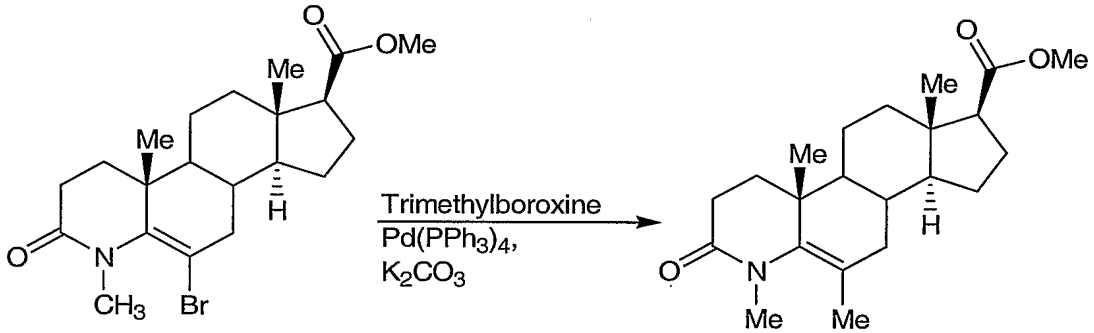
EXAMPLE 1



1-1 1-2

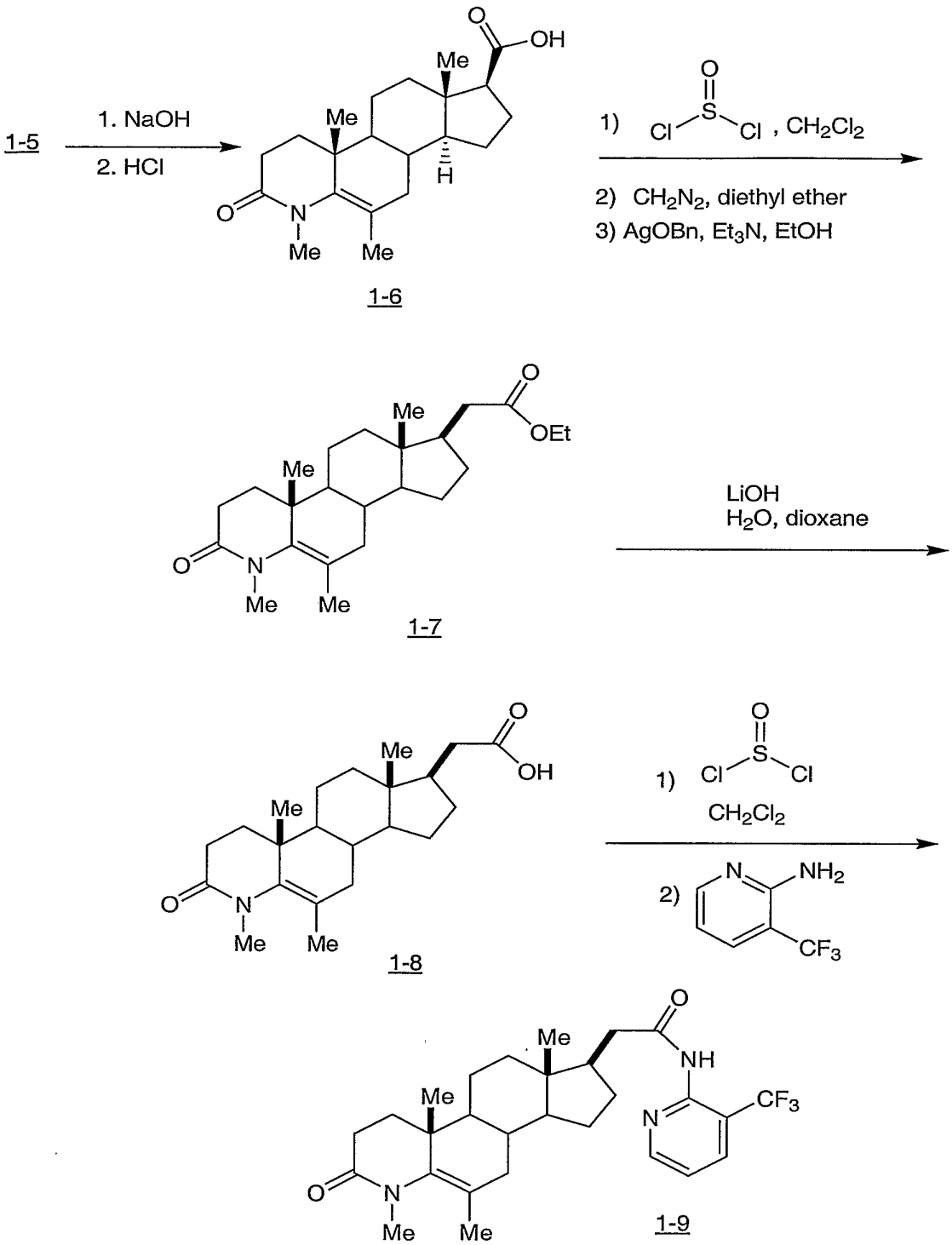


1-3



1-4 1-5

EXAMPLE 1 cont.



Step A: 3-Oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-2)

A mixture of 1-1, (J. Med. Chem., 29: 2298-2315 (1986)), (50.0 g, 157.5 mmol), EDC·HCl (33.2 g, 173.3 mmol) and DMAP (1.9 g, 15.8 mmol) in MeOH (300 mL) was stirred for 24 h. The mixture was concentrated and diluted with water (1000 mL). After filtration, the solid was collected and dried to furnish the desired product 1-2 as a solid which was used in Step B without further purification. MS calculated M+H: 332.2, found 332.2

Step B: 4-Methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-3)

To a suspension of 1-2 (7.0 g, 21.1 mmol) in 100 mL dry THF was added NaH (1.3 g, 32 mmol) gradually. The reaction mixture was stirred at rt for 1 h. Me_2SO_4 (10 mL) was added in one portion. The mixture was stirred overnight. MeOH (30 mL) was gradually added. After stirring for 3 h, water (500 mL) was added. A solid precipitated out immediately. After filtration, the collected solid was dissolved in chloroform and washed with brine and dried ($MgSO_4$). After solvent removal, the desired product 1-3 was collected as a solid and used in Step C without further purification. MS calculated M+H: 346.2, found 346.3

Step C: 6-Bromo-4-methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-4)

To a suspension of 1-3 (11 g, 33 mmol) in CCl_4 (100 mL) was added NBS (6.2 g, 45 mmol) and benzoyl peroxide (0.1 g, 0.5 mmol). The reaction mixture was refluxed for 4 h. The suspension was cooled and filtered. The filtrate was concentrated to provide the desired product 1-4, which was used in Step D without further purification.
MS calculated M+H: 424.1, found 424.2

Step D: 4-Methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-5)

A mixture of 1-4 (0.8 g, 1.8 mmol), K_2CO_3 (0.7 g, 5.3 mmol), $Pd(PPh_3)_4$ (0.2 g, 0.2 mmol) and trimethylboroxine (0.3 mL, 2.1 mmol) in DMF (15 mL) was purged with nitrogen for 10 min. The mixture was then heated at 100 °C overnight. The reaction was quenched with saturated aqueous $NaHCO_3$ and then water (200 mL). It was extracted three times with EtOAc. The combined organic layers were washed with water, brine and dried ($MgSO_4$). After solvent removal, the residue was purified by silica gel flash chromatography (100% EtOAc to 80% EtOAc/20% Hexanes) to afford the desired product 1-5 as a solid. MS calculated M+H: 360.3, found 360.3

Step E: 4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid (1-6)

To a solution of 1-5 (1.9 g, 5.3 mmol) in 1,4-dioxane (20 mL) was added NaOH (0.5 g) in 5 mL water. The mixture was refluxed overnight and acidified with 3N HCl and diluted with 50 mL water. The suspension was extracted three times with chloroform. The combined organic layers were washed with brine and dried ($MgSO_4$) and concentrated to provide the desired product 1-6 as a solid which was used in Step F with further purification. MS calculated M+H: 347.2, found 346.3

Step F: 4-Methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester (1-7)

To a stirred solution of 4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid 1-6 (10.0 g, 28.9 mmol) in anhydrous CH_2Cl_2 (150 ml) at 0° C was added anhydrous DMF (250 µl) and thionyl chloride (3.2 ml, 43.4 mmol). After stirring at 0° C for 30 min, anhydrous toluene (50 ml) was added and removed under vacuum at ambient temperature. This was repeated to give an orange oily solid. Meanwhile, to a suspension of 1-methyl-3-nitro-1-nitrosoguanidine (21.3 g, 144.7 mmol) in diethyl ether (175 ml) at -5° C in a polypropylene Erlenmeyer flask, cold 40% aqueous KOH solution (135 ml) was added slowly. After 40 min of stirring at -5° C, the biphasic diazomethane mixture was placed in a dry ice/acetone bath until aqueous phase was frozen (40 min). The deep yellow ether phase was filtered into a dry cold (-70° C) polypropylene Erlenmeyer flask. The frozen layer was rinsed with cold (-70° C) ether. This diazomethane solution was poured quickly into a solution of the acyl chloride in anhydrous CH_2Cl_2 (200 ml) at -5° C and stirred for 1 h. The remaining diazomethane was removed by vigorous bubbling of nitrogen into the reaction mixture and the solvent was removed under vacuum at ambient temperature to give a beige solid. This solid was dissolved in EtOH (100 ml) and the resulting solution was cooled to 0° C. Et_3N (4.8 ml, 34.7 mmol) and silver benzoate (6.6 g, 28.9 mmol) were added. Vigorous bubbling occurred. The dark brown mixture was allowed to warm to ambient temperature and was stirred over 2 h. Upon removal of the solvent under vacuum, the residue was purified over silica gel (100% hexane to 30% EtOAc/hexane) to give the title compound as a viscous yellow oil. MS M+H: 388.0.

Step G: 4-Methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (1-8)

To a stirred solution of 4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester 1-7 (9.5 g, 24.5 mmol) in dioxane (25 ml) and MeOH (10 ml) at 0° C was added LiOH (2.1 g, 49.0 mmol) as a solution in 20 ml water. The mixture was allowed to warm to ambient temperature. After 2 h of stirring, selective hydrolysis was complete. The mixture was diluted with water (100 ml) and extracted with EtOAc. The aqueous layer was acidified to pH = 3-4 with 3 N HCl. The precipitate was filtered and washed with water. After dissolving in $CHCl_3$, drying (MgSO4), and removal of the

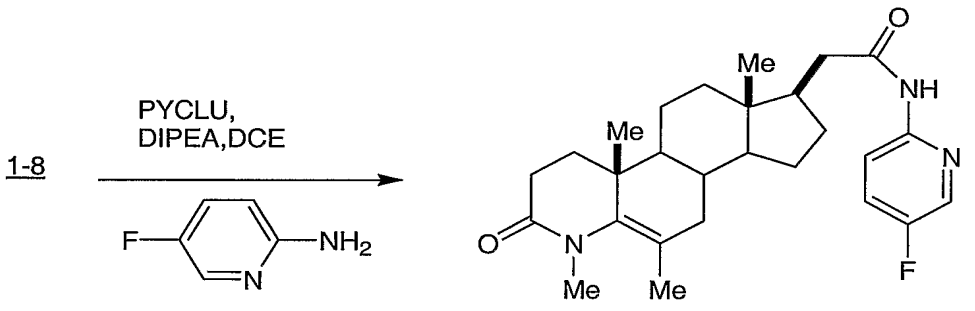
solvent under vacuum, the title compound was obtained as a white solid. ^{1}H NMR ($CDCl_3$) δ 0.64 (s, 3H), 0.97 (s, 3H), 1.05-1.39 (m, 6H), 1.43-1.86 (m, 12H), 1.97-2.28 (m, 5H), 2.44 (dd, 1H), 3.08 (s, 3H). MS M+H: 360.0.

Step H: N-[3-(trifluoromethyl)pyridin-2-yl]-4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (1-9)

To a stirred solution of 4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid 1-8 (0.05 g, 0.14 mmol) in anhydrous CH_2Cl_2 (1 ml) at 0° C was added anhydrous DMF (15μl) and thionyl chloride (15 μl, 0.21 mmol). The resulting solution was warmed to ambient temperature and stirred for 1 h. Anhydrous toluene (4 ml) was added and removed under vacuum at ambient temperature to give a yellow orange oil which was dissolved in anhydrous CH_2Cl_2 (0.5ml). DIPEA (0.12 ml, 0.70 mmol), DMAP (0.002 g, 0.014 mmol), and 2-amino-6-trifluoromethylpyridine (0.07 g, 0.42 mmol) were added. The mixture was heated in a microwave reactor at 120° C for 10 min. After removal of the solvent under vacuum, the residue was purified on reversed phase silica gel (5% CH_3CN/95% H_2O with 0.1% TFA to 80% CH_3CN/10% 95% H_2O with 0.1% TFA) to give the title compound as a yellow oil. MS calculated M+H: 504.2833, found 504.2823.

Examples 2 through 12 in Table 1 were prepared in a similar manner as compound 1-9, but using the appropriate amine to generate the final desired product.

EXAMPLE 13



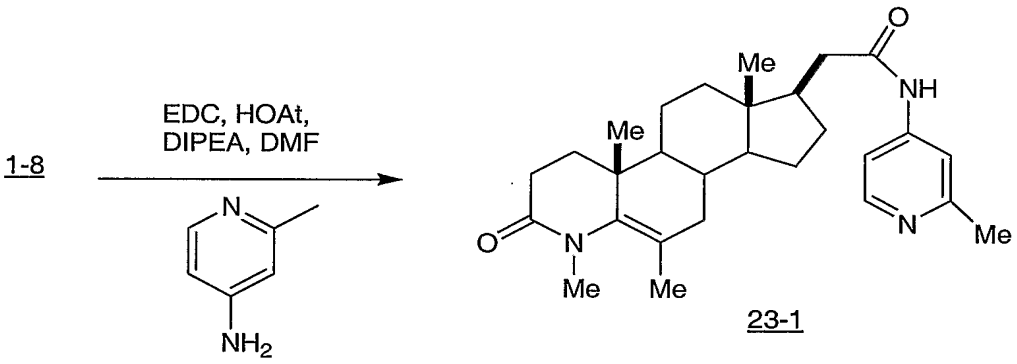
13-1

Step A: N-(5-fluoropyridin-2-yl)-4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (13-1)

4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid 1-8 (0.05g, 0.14 mmol) in anhydrous dichloroethane (2 ml) in an oven dried microwave tube was added PYCLU (0.07 g, 0.21mmol). The mixture was capped and stirred at ambient temperature for 5 min. DIPEA (0.12 ml, 0.70 mmol) and 2-amino-5-fluoropyridine (0.05 g, 0.42 mmol) were added and the mixture was heated in a microwave reactor at 180° C for 10 min. After removal of the solvent under vacuum, the residue was purified on reversed phase HPLC (35% CH_3CN/65% H_2O to 95% CH_3CN/5% H_2O over 10 minutes) to give the title compound as a beige solid. MS M+H: 454.0

Examples 14-22 in Table 1 were prepared in a similar manner as compound 13-1, but using the appropriate amine to generate the final desired product.

EXAMPLE 23



Step A: N-(2-methylpyridin-4-yl)-4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (23-1)

To a stirred solution of 4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (1-8) (5.0 g, 13.9 mmol) in anhydrous DMF (5 ml) was added EDC (5.3 g, 27.8 mmol), HOAt (2.8 g, 20.9 mmol), DIPEA (12.1 ml, 69.5 mmol), and 4-amino-2-methylpyridine (3.0 g, 27.8 mmol). The resulting orange mixture was heated at 100° C for 3 h and the solvent was removed under vacuum. The brown residue was partitioned between saturated aqueous $NaHCO_3$ solution and $CHCl_3$. The aqueous layer was extracted with $CHCl_3$ and the organic layers were combined. The organic layer was washed with water and brine. An orange oil was obtained after drying ($MgSO_4$) and removal of the solvent under vacuum. Purification on silica gel (100% $CHCl_3$ to 20% MeOH/ $CHCl_3$) gave the title compound as an

orange solid. ^{1}H NMR ($CDCl_3$) δ 0.68 (s, 3H), 0.98 (s, 3H), 1.07-1.28 (m, 4H), 1.35-1.42 (m, 1H), 1.45-1.69 (m, 10H), 1.73-1.82 (m, 2H), 1.89-1.95 (m, 1H), 2.00-2.10 (m, 2H), 2.15-2.28 (m, 2H), 2.48-2.53 (m, 4H), 3.09 (s, 3H), 7.23 (dd, 1H), 7.35 (d, 1H), 7.42 (s, 1H), 8.38 (d, 1H). MS calculated M+H: 450.3115, found 450.3115.

Examples 24-34 in Table 1 were prepared in a similar manner as compound 23-1, but using the appropriate amine to generate the final desired product.

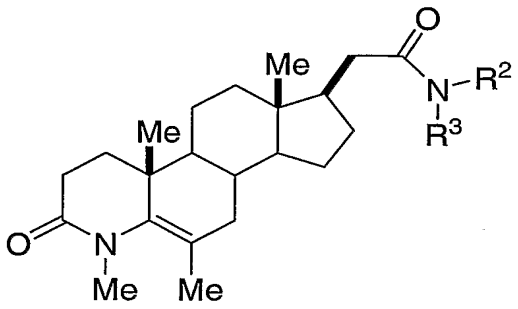
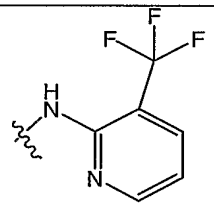
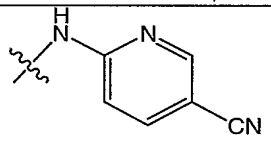
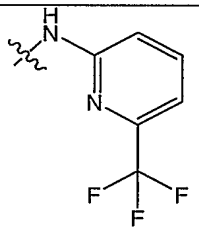
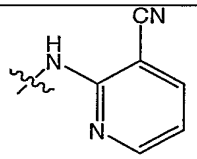
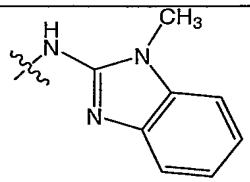
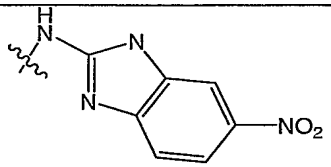
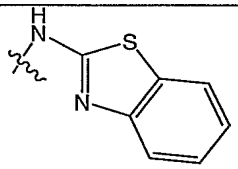
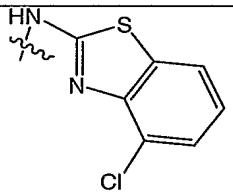
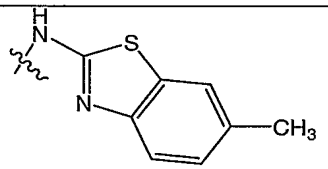
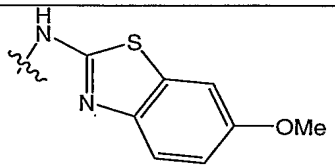
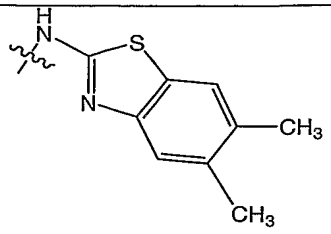
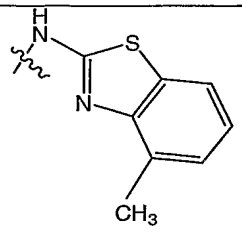
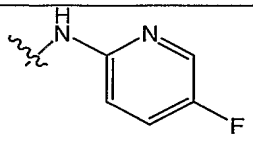
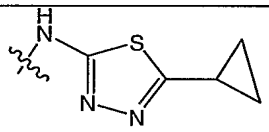
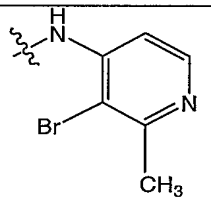
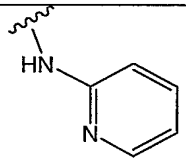
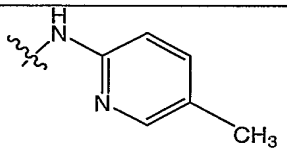
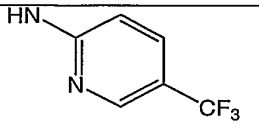
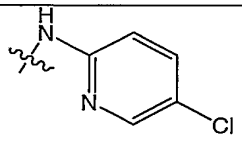
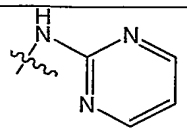
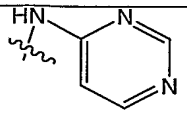
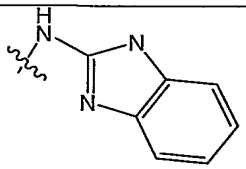
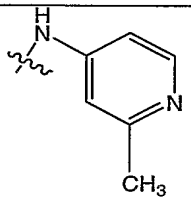
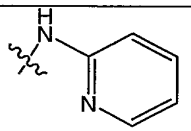
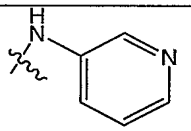
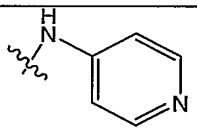
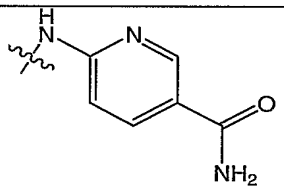
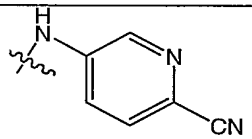
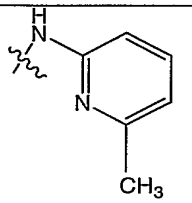


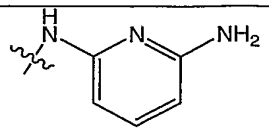
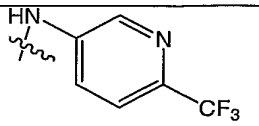
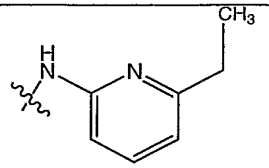
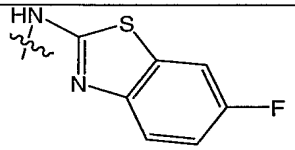
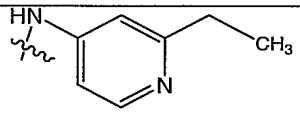
Table 1

Ex.	NR^2R^3	Name	Mass spectrum Measured [M+H]
1		*N*-[3-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	504.2823
2		*N*-(5-cyanopyrid-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	461.1
3		*N*-[6-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	504.2823

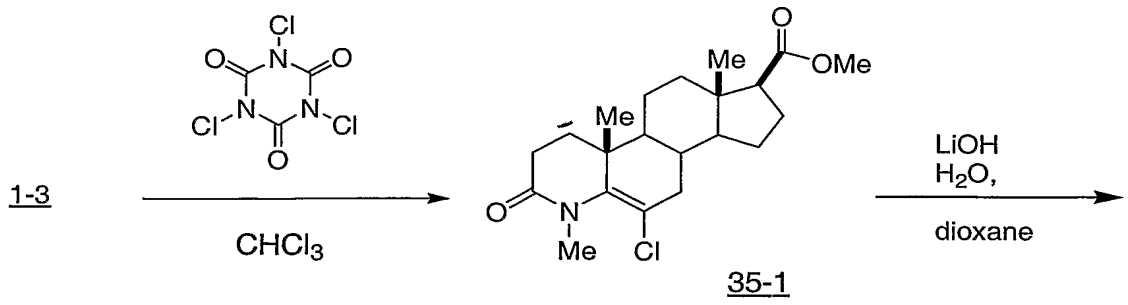
4		*N*-[3-cyano-pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	461.2921
5		*N*-(3-methyl-benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	489.3216
6		*N*-(5-nitro-benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	520.2944
7		*N*-(1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	492.2676
8		*N*-(4-chloro-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	526.2289
9		*N*-(6-methyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	506.2832
10		*N*-(6-methoxy-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	522.2766

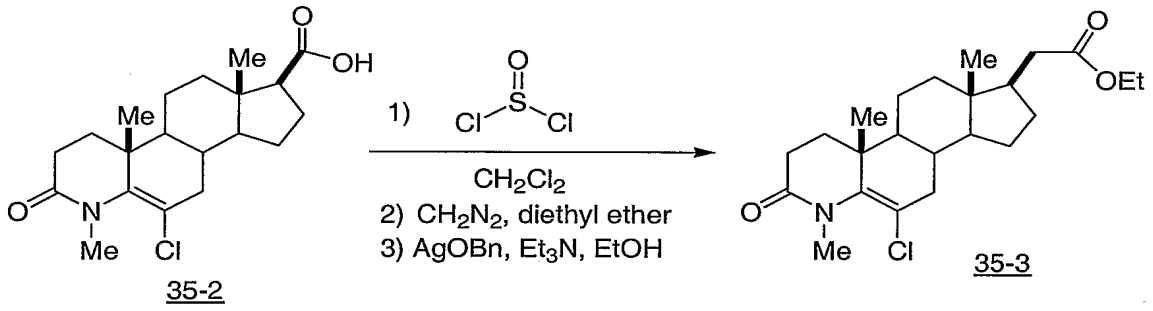
11		*N*-(5,6-dimethyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	503.3405
12		*N*-(4-methyl-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	506.2834
13		*N*-(5-fluoropyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	454.0
14		*N*-(5-cyclopropyl-1,3,4-thiadiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	483.2794
15		*N*-(2-methyl-3-bromo-pyrid-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	530.33
16		*N,N*-methyl(pyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	450.1
17		*N*-(5-methylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	450.0
18		*N*-[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	504.39
19		*N*-(5-chloropyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.36

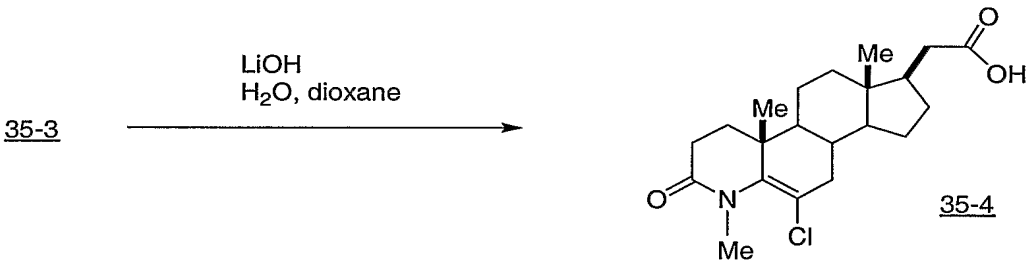
20		*N*-(1,3-pyrimid-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide -	437.1
21		*N*-(1,3-pyrazin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	437.1
22		*N*-(benzimidazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	475.1
23		*N*-(2-methyl-pyrid-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	450.3115
24		*N*-(pyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	436.2958
25		*N*-(pyridin-3-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	436.2947
26		*N*-(pyridin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	436.2951
27		*N*-[(3-carboxamido)-pyridin-6-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	479.3046
28		*N*-(6-cyanopyridin-3-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	461.2901
29		*N*-(6-methylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	450.3117

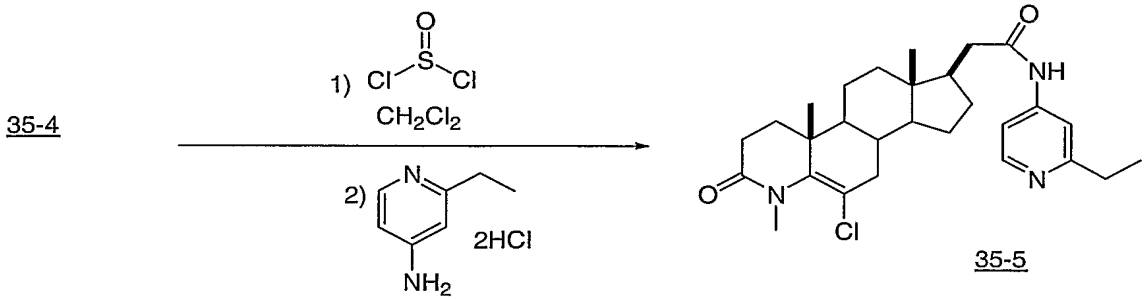
30		*N*-(6-aminopyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	451.3069
31		*N*-[(6-trifluoromethyl)-pyrid-3-yl] -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	504.2833
32		*N*-(6-ethylpyridin-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	464.3274
33		*N*-(6-fluoro-1,3-benzothiazol-2-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	510.2572
34		*N*-(2-ethylpyridin-4-yl) -4-methyl-6-methyl-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	464.1

EXAMPLE 35


1-3
CHCl3
35-1
LiOH
H2O,
dioxane


35-2
1)
CH2Cl2
2) CH2N2, diethyl ether
3) AgOBn, Et3N, EtOH
35-3


35-3
LiOH
H2O, dioxane
35-4


35-4
1)
CH2Cl2
2)
2HCl
35-5

Step A: 4-Methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid ethyl ester (35-1)

To a stirred solution of 4-methyl-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-3) (10.0 g, 30.2 mmol) in $CHCl_3$ (250 ml) was added trichloroisocyanuric acid (2.3 g, 9.9 mmol). The resulting solution was stirred at ambient temperature for 18 h. The mixture was partitioned between ethyl acetate and water. The organic layer was washed with 10% aqueous $KHSO_4$ solution, saturated aqueous $NaHCO_3$ solution, and saturated aqueous brine solution. After drying ($MgSO_4$) and removal of the solvent under vacuum, the title compound was obtained as a pale yellow solid. ^1H NMR ($CDCl_3$) δ 0.72 (s, 3H), 1.13-1.40 (m, 5H), 1.41-1.80 (m, 5H), 1.81-2.09 (m, 5H), 2.10-2.28 (m, 1H), 2.29-2.56 (m, 3H), 3.68 (s, 3H). MS M+H: 379.9.

Step B: 4-Methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid (35-2)

To a stirred solution of 4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid ethyl ester (35-1) (1.0 g, 2.7 mmol) in dioxane (5 ml) is added lithium hydroxide (0.3 g, 8.1 mmol) as a solution in 5 ml water. The resulting mixture was heated at 50°C for 18 h. Dioxane was removed under vacuum and the pH was adjusted to 3-4 with 3 N HCl. The solid that precipitated was filtered and washed with water. After drying azeotropically with toluene, the title compound was obtained as a white solid. ^1H NMR (CD_3OD) δ 0.76 (s, 3H), 1.06 (s, 3H), 1.07-1.44 (m, 5H), 1.46-1.60 (m, 3H), 1.64-2.04 (m, 5H), 2.08-2.25 (m, 4H), 2.30-2.53 (m, 5H). MS M+H: 366.2.

Step C: 4-Methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester (35-3)

To a stirred solution of 4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid (35-2) (10.0 g, 27.3 mmol) in anhydrous CH_2Cl_2 (150 ml) at 0° C was added anhydrous DMF (250 µl) and thionyl chloride (3.0 ml, 41.0 mmol). After stirring at 0° C for 30 min, anhydrous toluene (50 ml) was added and removed under vacuum at ambient temperature. This concentration was repeated to give an orange oily solid. Meanwhile, to a suspension of 1-methyl-3-nitro-1-nitrosoguanidine (20.1g, 136.7 mmol) in diethyl ether (175 ml) at -5° C in a polypropylene Erlenmeyer flask, cold 40% aqueous KOH solution (135 ml) was added slowly. After 40 min of stirring at -5° C, the biphasic diazomethane mixture was placed in a dry ice/acetone bath until the aqueous phase was frozen (40 min). The deep yellow ether phase was filtered into a dry cold (-70° C) polypropylene Erlenmeyer flask. The frozen layer was rinsed with cold (-70° C) ether. The diazomethane solution was poured quickly into a solution of the acyl chloride in anhydrous CH_2Cl_2 (200 ml) at -5° C and stirred for 1 h. The remaining diazomethane was removed by vigorous bubbling of nitrogen into reaction mixture and the solvent was removed under

vacuum at ambient temperature to give a beige solid. This solid was dissolved in EtOH (100 ml). The resulting solution was cooled to 0° C. Et_3N (4.6 ml, 32.8 mmol) and silver benzoate (6.3g, 27.3 mmol) were added. Vigorous bubbling occurred. The dark brown mixture was allowed to warm to ambient temperature. After 2 hr of stirring at ambient temperature, the ethanol was removed under vacuum. The residue was purified on silica gel (100% hexane to 30% EtOAc/hexane) to give the title compound as a viscous yellow oil. ^1H NMR ($CDCl_3$) δ 0.65 (s, 3H), 1.04 (s, 3H), 1.08-1.16 (m, 1H), 1.16-1.29 (m, 4H), 1.32-1.39 (m, 1H), 1.45-1.55 (m, 1H), 1.57-1.61 (m, 7H), 1.62-1.74 (m, 3H), 1.81-1.87 (m, 1H), 1.94-2.02 (m, 1H), 2.05-2.18 (m, 2H), 2.21-2.46 (m, 3H), 3.20 (s, 3H), 4.13 (q, 2H). MS M+H: 408.0.

Step D: 4-Methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (35-4)

To a stirred solution of 4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester (35-3) (7.7g, 18.8 mmol) in dioxane (25 ml) and MeOH (10 ml) at 0° C was added (1.6g, 37.5 mmol) LiOH as a solution in 20 ml water. The mixture was allowed to warm to ambient temperature. After 2.0 h of stirring at ambient temperature, selective hydrolysis was complete. The mixture was diluted with 100 ml water and extracted with EtOAc. The aqueous layer was acidified to pH = 3-4 with 3 N HCl. The precipitate was filtered and washed with water. After dissolving in $CHCl_3$, drying ($MgSO_4$), and removal of the solvent under vacuum; the title compound was obtained as a white solid. ^1H NMR (CD_3OD) δ 0.70 (s, 3H), 1.15-1.21 (m, 2H), 1.24-1.46 (m, 3H), 1.53-1.61 (m, 2H), 1.64-1.70 (m, 1H), 1.72-1.80 (m, 2H), 1.81-1.87 (m, 2H), 1.92-2.04 (m, 3H), 2.08-2.18 (m, 2H), 2.22-2.26 (m, 2H), 2.35-2.48 (m, 2H), 3.18 (s, 3H). MS M+H: 380.0.

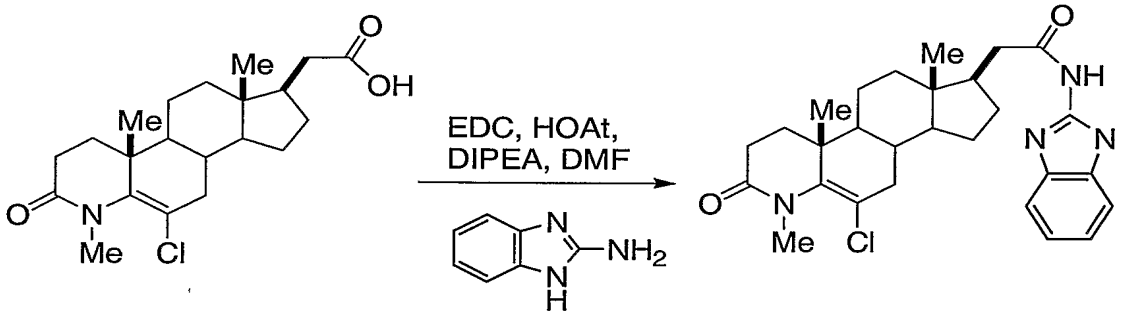
Step E: N-(2-ethylpyridin-4-yl)-4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (35-5)

To a stirred solution of 4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (35-4) (0.10g, 0.26mmol) in anhydrous CH_2Cl_2 (1 ml) at 0° C was added anhydrous DMF (15 µl) and thionyl chloride (30 µl, 0.40 mmol). The resulting solution was warmed to ambient temperature and stirred for 1 h. Anhydrous toluene (4 ml) was added and removed under vacuum at ambient temperature to give an orange oil which was dissolved in anhydrous CH_2Cl_2 (0.5 ml). DIPEA (0.23 ml, 1.32 mmol), DMAP (0.003 g, 0.03 mmol), and 4-amino-2-ethylpyridine hydrochloride (0.08 g, 0.40 mmol) were added and mixture was heated in a microwave reactor at 120° C for 10 min. CH_2Cl_2 was removed under vacuum and the residue was purified on reversed phase silica gel (5% CH_3CN/95% H_2O with 0.1% TFA to 80% CH_3CN/10% 95% H_2O with 0.1% TFA) to give the title compound as a yellow oil. ^1H NMR ($CDCl_3$) δ 0.67 (s, 3H), 1.04 (s, 3H), 1.14-1.29 (m, 5H), 1.37 (t, 3H), 1.41-1.75 (m, 6H), 1.81-1.86 (m,

1H), 1.91-2.04 (m, 2H), 2.09 (dd, 1H), 2.21-2.30 (m, 1H), 2.31-2.46 (m, 3H), 2.60-2.64 (m, 1H), 2.96 (q, 2H), 7.76 (s, 1H), 8.23 (s, 1H), 8.31 (s, 1H). MS calculated M+H: 484.2726, found 484.2709.

Examples 36-55 in Table 2 were prepared in a similar manner as compound (35-5), but using the appropriate amine to generate the final desired product.

EXAMPLE 56



35-4 56-1

N-(benzimidazole-2-yl)-4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (56-1)

To a stirred solution of 4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (35-4) (0.25 g, 0.70 mmol) in 2 ml anhydrous DMF, was added EDC (0.27 g, 1.39 mmol), HOAt (0.14 g, 1.04 mmol), DIPEA (0.61 ml, 3.48 mmol), and 2-aminobenzimidazole (0.28 g, 2.09 mmol). The resulting mixture was heated in a microwave reactor at 100° C for 20 min. The crude reaction mixture was purified on reversed phase silica gel (0% CH_3CN/100% H_2O to 50%CH_3CN/50% H_2O over 7 minutes then 50%CH_3CN/50% H_2O for 5 minutes) to give the title compound as a beige solid. MS calculated M+H: 495.2522, found 495.2534.

Examples 57-59 in Table 2 were prepared in a similar manner as compound (56-1), but using the appropriate amine to generate the final desired product.

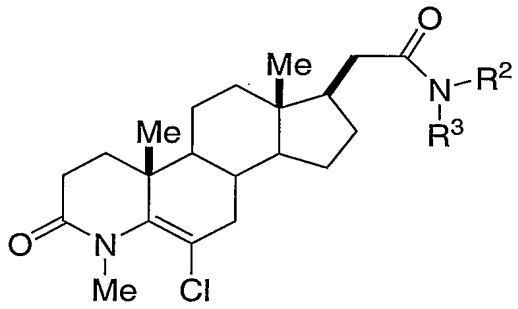
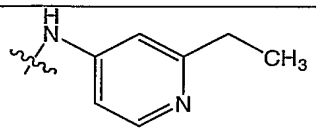
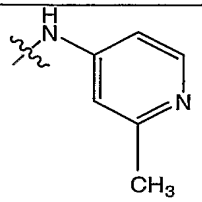
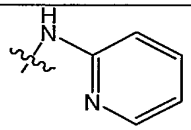
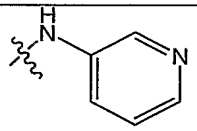
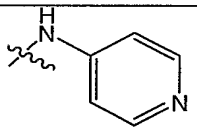
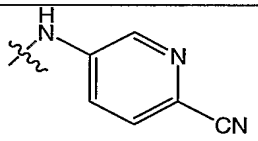
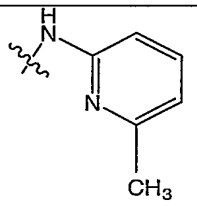
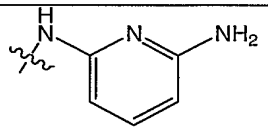
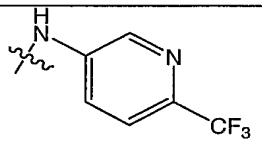
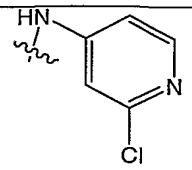
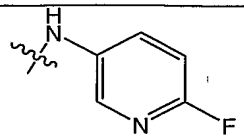
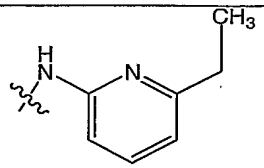
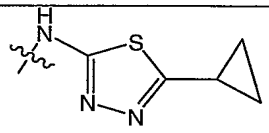
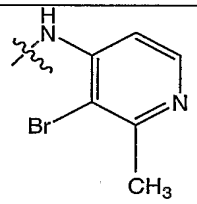
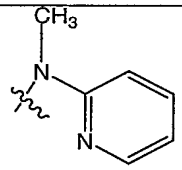
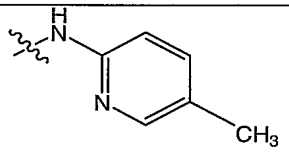
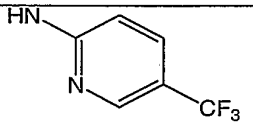
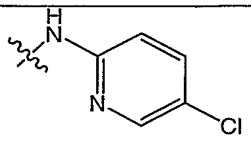
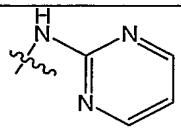
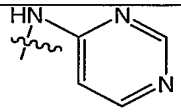
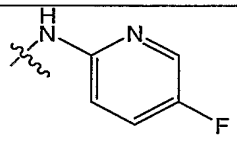
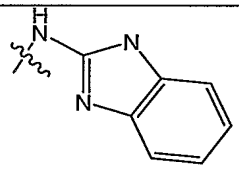
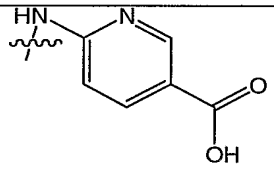
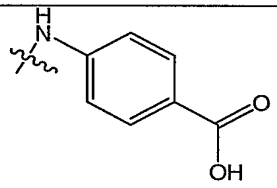
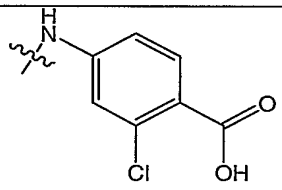


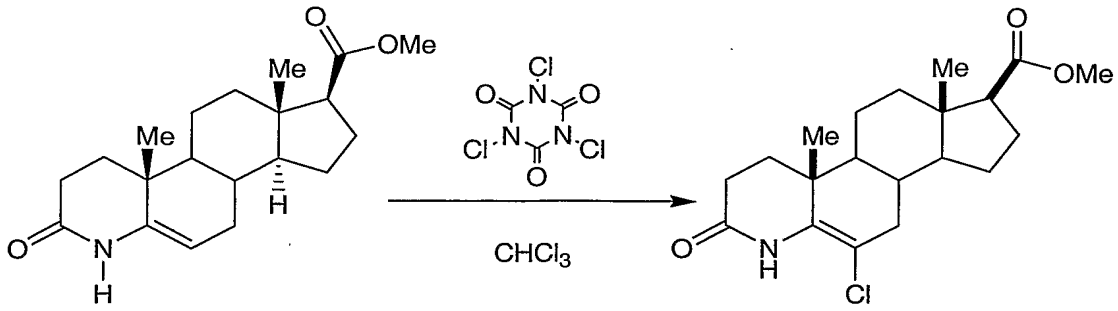
Table 2

Ex.	NR^2R^3	Name	Mass spectrum Measured [M+H]
35		*N*-(2-ethylpyridin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	484.2709
36		*N*-(2-methyl-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.2598
37		*N*-(pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.2446
38		*N*-(pyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.2418
39		*N*-(pyridin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.2448
40		*N*-(6-cyanopyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	481.2398
41		*N*-(6-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.2595
42		*N*-(6-aminopyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	471.2548
43		*N*-[(6-trifluoromethyl)-pyrid-3-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	524.2295

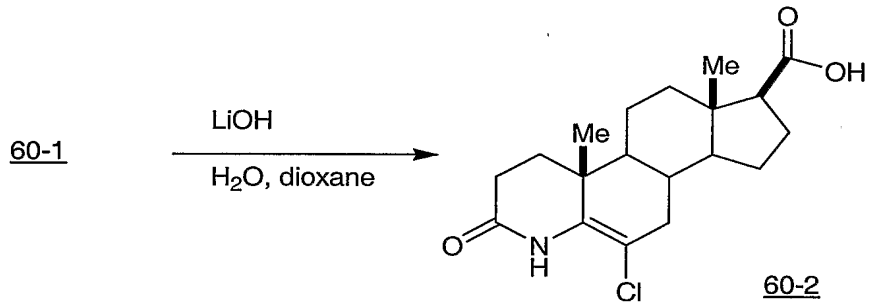
44		*N*-(2-chloro-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	490.2024
45		*N*-(5-fluoro-pyrid-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	474.234
46		*N*-(6-ethylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	484.2739
47		*N*-(5-cyclopropyl-1,3,4-thiadiazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	503.2256
48		*N*-(2-methyl-3-bromo-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	548.1694
49		*N,N*-methyl(pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.2576
50		*N*-(5-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.256
51		*N*-[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	524.2289

52		*N*-(5-chloropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	490.2031
53		*N*-(1,3-pyrimid-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide -	457.2382
54		*N*-(1,3-pyrazin-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	457.2382
55		*N*-(5-fluoropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	474.2334
56		*N*-(benzimidazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	495.2534
57		*N*-[(5-carboxyl)-pyrid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	500.2311
58		*N*-[(4-carboxyl)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	499.239
59		*N*-[(4-carboxyl-3-chloro)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	533.1997

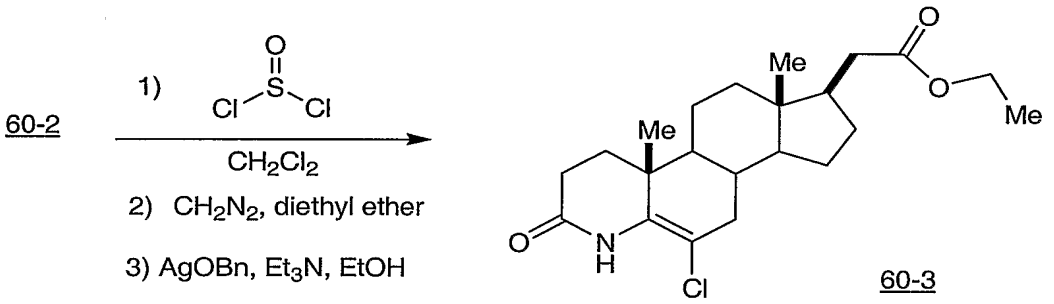
EXAMPLE 60



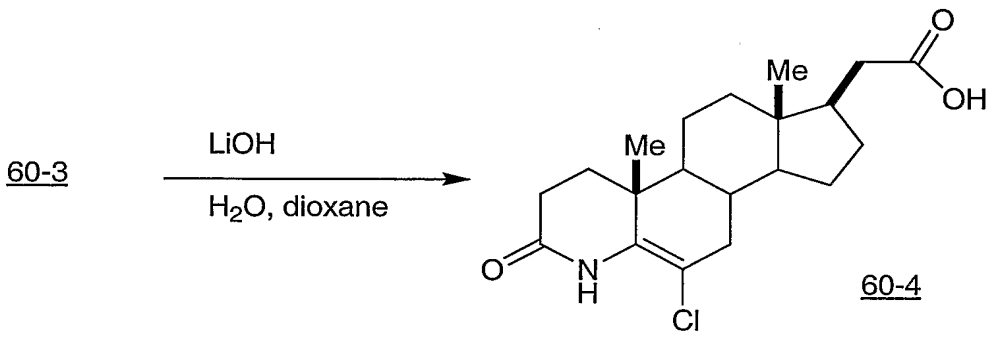
1-2 60-1



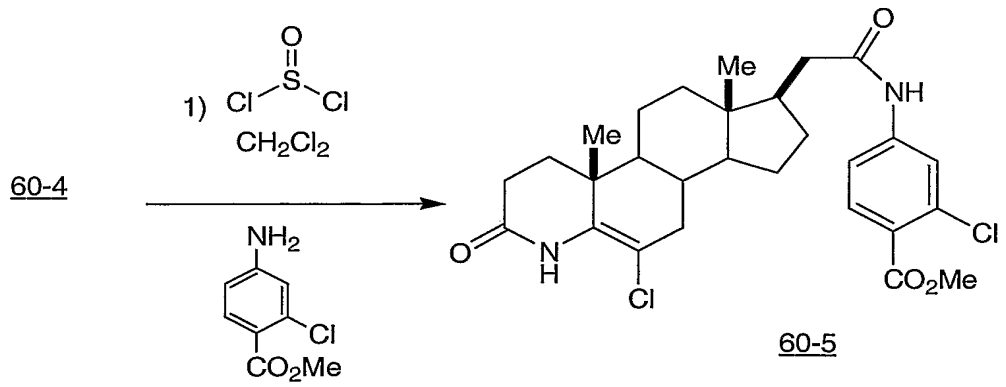
60-2



60-3



60-4



Step A: 6-Chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid ethyl ester (60-1)

To a stirred solution of 3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid methyl ester (1-2) (50.0 g, 150.9 mmol) in $CHCl_3$ (1 L) was added trichloroisocyanuric acid (11.6 g, 49.8 mmol). The resulting solution was stirred at ambient temperature for 18 h. The mixture was partitioned between ethyl acetate and water. The organic layer was washed with 10% aqueous brine solution and dried ($MgSO_4$). The solvent was removed under vacuum to give the title compound as a yellow solid. ^1H NMR ($CDCl_3$) δ 0.7 (s, 3H), 1.13 (s, 3H), 1.17-1.37 (m, 7H), 1.40-1.67 (m, 4H), 1.70-1.76 (m, 1H), 1.77-1.90 (m, 2H), 1.91-1.98 (m, 1H), 2.09-2.23 (m, 2H), 2.37-2.44 (m, 2H), 2.45-2.56 (m, 2H), 3.68 (m, 3H). MS M+CH_3CN: 406.9.

Step B: 6-Chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid (60-2)

To a stirred solution of 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid ethyl ester (60-1) (46.0 g, 121.0 mmol) in dioxane (100.0 ml) was added LiOH (15.2 g, 363.2 mmol) as a solution in 100 ml water and the resulting mixture was heated at 50°C for 18 h. The dioxane was removed under vacuum and the pH was adjusted to 3-4 with 3 N HCl. The precipitate was filtered and washed with water. The solid was dissolved in a solution of $CHCl_3$/isopropanol (4:1) and the solvent was removed under vacuum. After drying azeotropically with toluene, the title compound was obtained as an orange foam. ^1H NMR (CD_3OD) δ 0.76 (s, 3H), 1.15 (s, 3H), 1.24-1.60 (m, 6H), 1.66-1.77 (m, 3H), 1.79-1.89 (m, 2H), 2.00-2.14 (m, 4H), 2.24-2.72 (m, 4H). MS M+CH_3CN: 393.0.

Step C: 6-Chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester (60-3)

To a stirred solution of 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid (6-2) in anhydrous CH_2Cl_2 (150 ml) at 0^0 C was added anhydrous DMF (250 μl) and thionyl chloride (2.5 ml, 34.1 mmol). After stirring at 0° C for 30 min, anhydrous toluene (50.0 ml) was added and removed under

vacuum at ambient temperature. This was repeated to give an orange oily solid. Meanwhile, to a suspension of 1-methyl-3-nitro-1-nitrosoguanidine (16.7 g, 113.7 mmol) in diethyl ether (175 ml) at -5° C in a polypropylene Erlenmeyer flask, cold 40% aqueous KOH solution (135 ml) was added slowly. After 40 min of stirring at -5° C, the biphasic diazomethane mixture was placed in a dry ice/acetone bath until aqueous phase was frozen (40 min). The deep yellow ether phase was filtered into a dry cold (-70° C) polypropylene Erlenmeyer flask and the frozen layer was rinsed with cold (-70° C) ether. The diazomethane solution was poured quickly into a solution of the acyl choride in anhydrous CH_2Cl_2 (200.0 ml) at -5°C and stirred for 1 h. The remaining diazomethane was removed by vigorous bubbling of nitrogen into reaction mixture and the solvent was removed under vacuum at ambient temperature to give a beige solid. The solid was dissolved in EtOH (100 ml) and the resulting solution was cooled to 0° C. Et_3N (3.8 ml, 27.3 mmol) and silver benzoate (5.2g, 22.7 mmol) were added. Vigorous bubbling occurred. The dark brown mixture was allowed to warm to ambient temperature. After 2.0 h of stirring at ambient temperature, the ethanol was removed under vacuum. The residue was purified on silica gel (100% hexane to 30% EtOAc/hexane) to give the title compound as a viscous yellow oil containing 15% 6-Chloro-3-oxo-4-aza-5α-androst-5-en-17β-carboxylic acid ethyl ester. ^1H NMR ($CDCl_3$) δ 0.65 (s, 3H), 1.14 (s, 3H), 1.16-1.28 (m, 5H), 1.31-1.62 (m, 6H), 1.64-1.73 (m, 2H), 1.75-1.87 (m, 2H), 1.93-2.00 (m, 2H), 2.05-2.19 (m, 2H), 2.35-2.41 (m, 2H), 2.51-2.53 (m, 2H), 4.12 (q, 2H), 7.53 (s, 1H). MS M+H: 366.0.

Step D: 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (60-4)

To a stirred solution of 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid ethyl ester (60-3) (2.2 g, 5.6 mmol) in dioxane (25 ml) and MeOH (10 ml) at 0° C was added (0.47 g, 11.7 mmol) LiOH as a solution in 20 ml water. The mixture was allowed to warm to ambient temperature. After 2 h of stirring, selective hydrolysis was complete. The mixture was diluted with 100 ml water and extracted with EtOAc. The aqueous layer was acidified to pH 3-4 with 3.0 N HCl. The precipitate was filtered and washed with water. The title compound was obtained as a white solid after dissolving in $CHCl_3$, drying (MgSO4), and removing the solvent under vacuum. ^1H NMR ($CDCl_3$) δ 0.65 (s, 3H), 1.10-1.27 (m, 5H), 1.33-1.55 (m,3H), 1.60-1.63 (m, 1H), 1.68-1.87 (m, 4H), 1.92-1.98 (m, 1H), 1.99-2.12 (m, 2H), 2.18-2.23 (m, 2H), 2.36-2.48 (m, 3H), 2.51-2.57 (m, 2H). MS M+H 352.0.

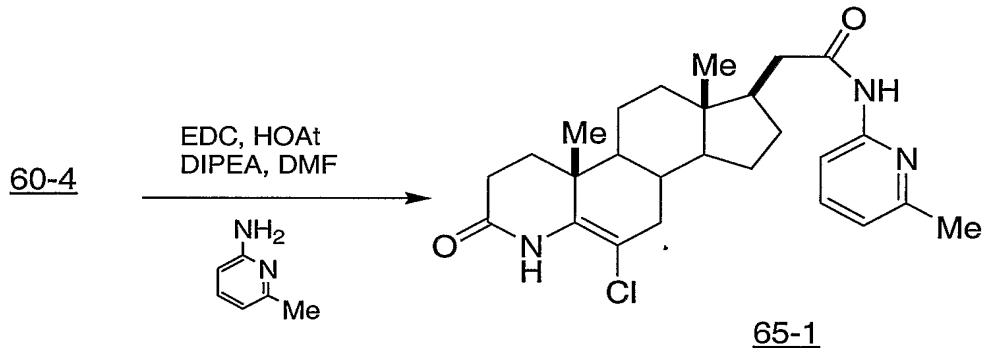
Step E: N-[2-chloro(4-methoxycarbonyl)phenyl]-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (60-5)

To a stirred solution of 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (60-4)(0.05 g, 0.14 mmol) in anhydrous CH_2Cl_2 (1 ml) at 0° C was added anhydrous DMF (10 µl) and thionyl

chloride (15 µl, 0.21 mmol). The resulting orange solution was warmed to ambient temperature and stirred for 1 h. Anhydrous toluene (2 ml) was added and removed under vacuum at ambient temperature to give an orange oil which was dissolved in anhydrous CH_2Cl_2 (0.5 ml). DIPEA (0.12 ml, 0.68 mmol), DMAP (0.002 g, 0.014 mmol), and methyl 4-amino-3-chlorobenzoate (0.08 g, 0.41 mmol) was added. After stirring at ambient temperature for 18 h, CH_2Cl_2 was removed under vacuum. The residue was purified on reversed phase silica gel (5% CH_3CN/95% H_2O with 0.1% TFA to 80% CH_3CN/10% 95% H_2O with 0.1% TFA) to give the title compound as a pale yellow solid. ^1H NMR ($CDCl_3$) δ 0.72 (s, 3H), 1.15 (s, 3H), 1.17-1.31 (m, 3H), 1.40-1.56 (m, 3H), 1.61-1.65 (m, 1H), 1.72-1.86 (m, 3H), 1.92-1.99 (m, 3H), 2.05-2.13 (m, 2H), 2.28 (dd, 1H), 2.40 (dd, 1H), 2.52-2.58 (m, 3H), 3.92 (s, 3H), 7.56 (s, 1H), 7.81 (s, 1H), 7.95 (d, 1H), 8.08 (s, 1H), 8.54 (d, 1H). MS calculated M+H: 533.1969, found 533.1974.

Examples 61-64 in Table 3 were prepared in a similar manner as compound 60-5, but using the appropriate amine to generate the final desired product.

EXAMPLE 65



65-1

N-(6-methylpyridin-2-yl)-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide (65-1)

To a stirred solution of 6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetic acid (60-4) (0.05 g, 0.14 mmol) in 0.5 ml anhydrous DMF was added EDC (0.03 g, 0.14 mmol), HOAt (0.02 g, 0.14 mmol), DIPEA (0.12 ml, 0.68 mmol), and 2-amino-6-picoline (0.04 g, 0.41 mmol). The resulting mixture was heated at 100° C in a microwave reactor for 10 min. Purification of the crude mixture on reversed phase silica gel (5% CH_3CN/95% H_2O with 0.1% TFA to 80% CH_3CN/10% 95% H_2O with 0.1% TFA) gave the title compound as a colorless oil. MS calculated M+H: 456.2413, found 456.2382.

Examples 66-69 and 71-75 in Table 3 were prepared in a similar manner as compound (65-1), but using the appropriate amine to generate the final desired product.

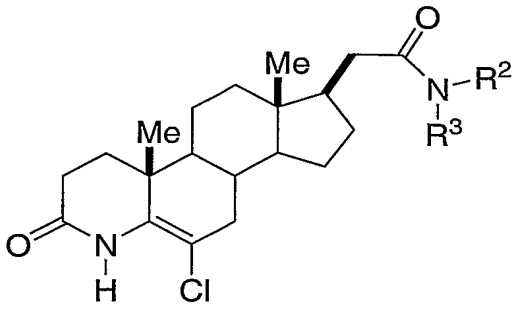
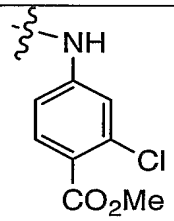
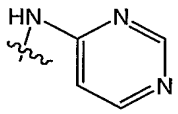
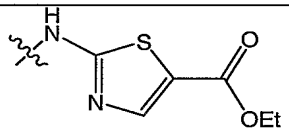
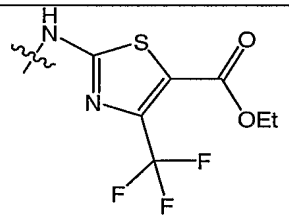
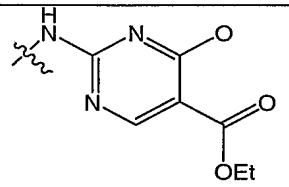
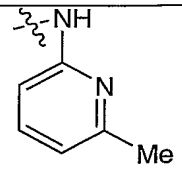
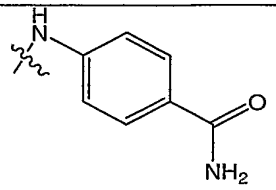
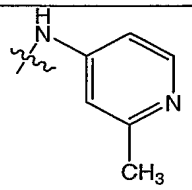
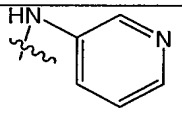
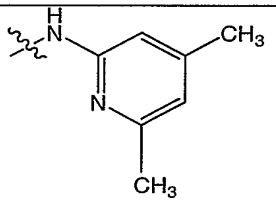
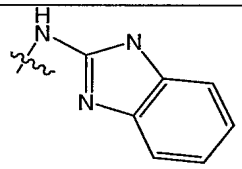
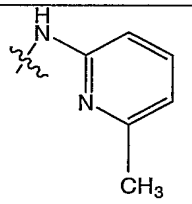
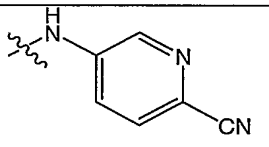
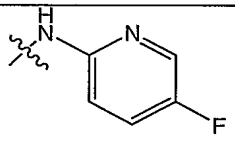
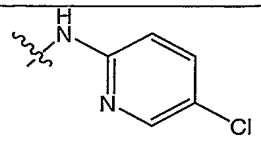
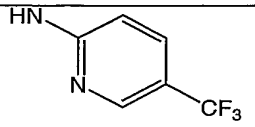
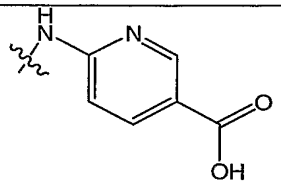


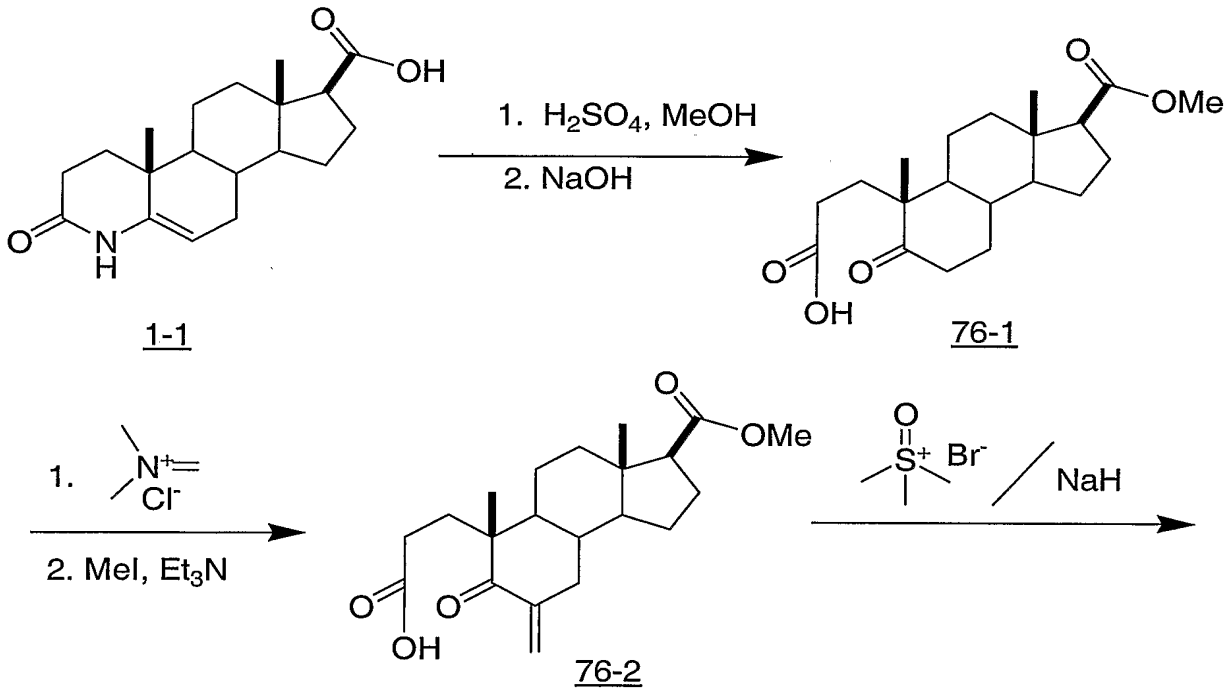
Table 3

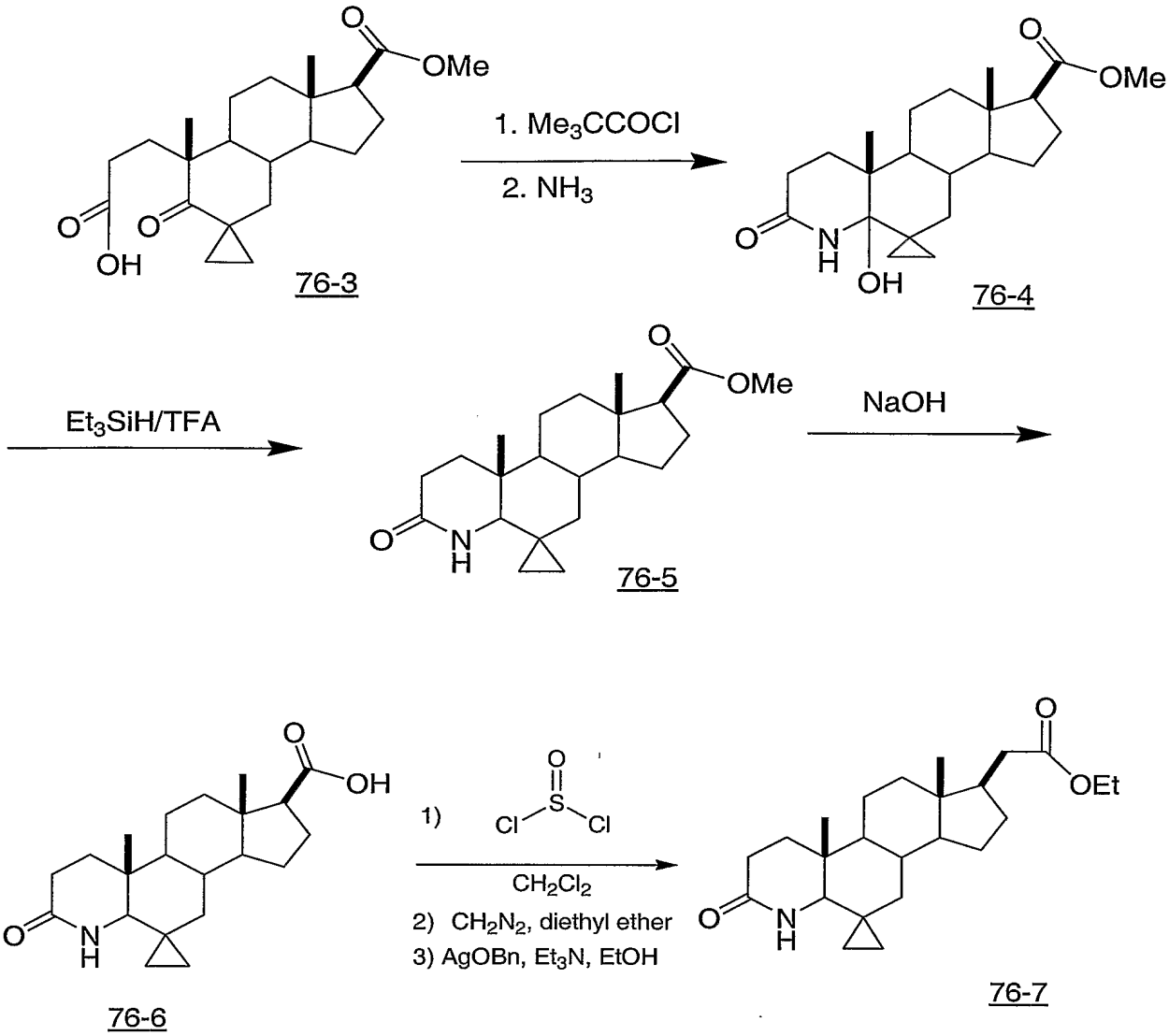
Ex.	NR^2R^3	Name	Mass spectrum Measured [M+H]
60		*N* -[2-chloro(4-methoxycarbonyl)phenyl]-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	533.1974
61		*N* -(1,3-pyrimid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	443.2193
62		*N* -[5-(ethoxycarbonyl) -1,3-thiazol-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	520.2026
63		*N* -[4-(trifluoromethyl)-5-(ethoxycarbonyl) -1,3-thiazol-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	588.1926
64		*N* -[4-hydroxy-5-(ethoxycarbonyl) -1,3-pyrimid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	531.2372

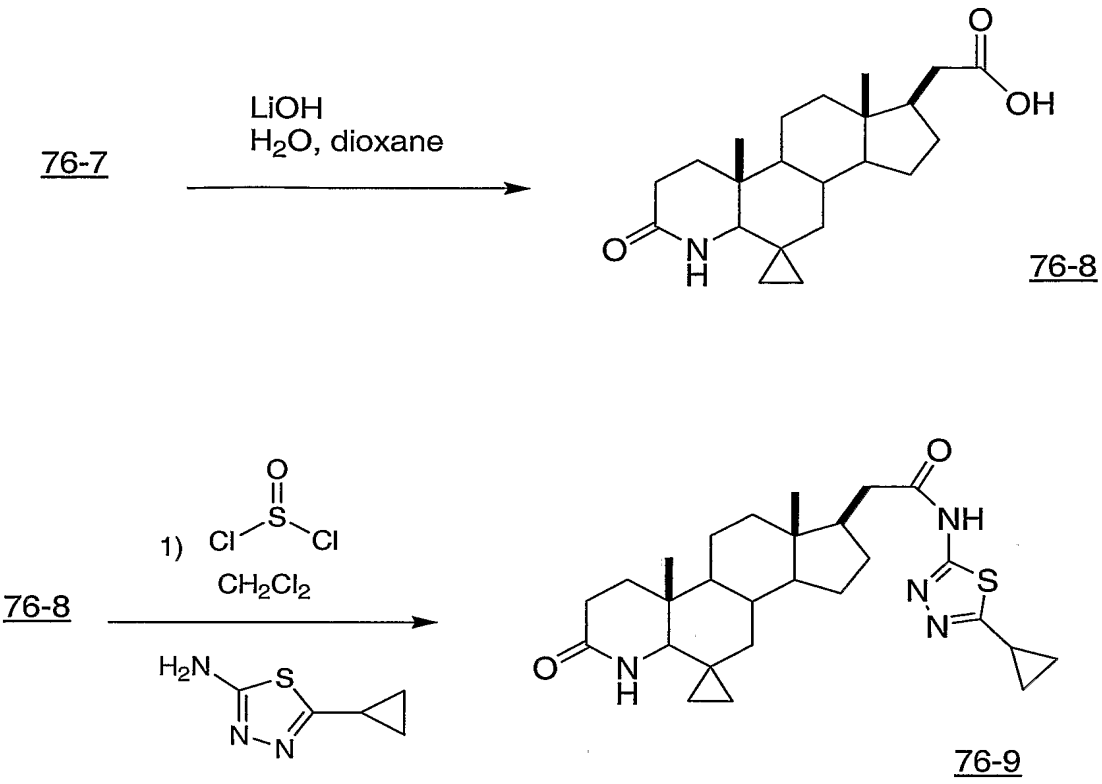
65		*N* -(6-methylpyridin-2-yl)-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.2382
66		*N* -[(4-carboxamido)phenyl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	484.9
66		*N* -(2-methyl-pyrid-4-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.0
67		*N* -(pyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	441.9
68		*N* -(4,6-dimethylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	470.2533
69		*N* -(benzimidazol-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	481.2366
70		*N* -(6-methylpyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	456.2382
71		*N* -(6-cyanopyridin-3-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	467.2209
72		*N* -(5-fluoropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	460.214

73		*N* -(5-chloropyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	476.1867
74		*N* -[5-(trifluoromethyl)pyridin-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	510.2122
75		*N*-[(5-carboxyl)-pyrid-2-yl] -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide	486.2145

EXAMPLE 76




OMe
1. Me3CCOCl
2. NH3
OH
76-3
76-4
Et3SiH/TFA
NaOH
76-5
OH
1)
CH2Cl2
2) CH2N2, diethyl ether
3) AgOBn, Et3N, EtOH
OEt
76-6
76-7



Step A: Methyl (3S,3aS,6R)-6-(3-methoxy-3-oxopropyl)-3a,6-dimethyl-7-oxododecahydro-1H-cyclopenta[a]naphthalene-3-carboxylate (76-1)

To a suspension of 1-1 (50 g, 157.5 mmol) in 400 mL methanol cooled at 0 °C was added conc. H_2SO_4 (50 mL) slowly. After the addition, the reaction mixture was heated to 50 °C overnight. After removal of the solvent, the residue was poured into ice. The mixture was extracted with EtOAc (x3). The combined organic layers was washed with water, sat $NaHCO_3$, brine and dried ($MgSO_4$). Removal of the solvent afforded a yellow oil which was dissolved in 100 mL methanol. The solution was then cooled to 0 °C. A cooled (0 °C) solution of NaOH (6.5 g, 159.7 mmol) was added. The mixture was stirred overnight, treated with 3N HCl and concentrated. The residue was extracted with CH_2Cl_2 (x3). The combined organic layers were washed with water, brine, and dried ($MgSO_4$). Removal of the solvent afforded the desired product 76-1 as a white solid, which was used for the next step without further purification.

MS calculated M+H: 351.5, found 351.0

Step B: 3-[(3S,3aS,6R)-3-(methoxycarbonyl)-3a,6-dimethyl-8-methylene-7 oxododecahydro-1H-cyclopenta[a]naphthalen-6-yl]propanoic acid (76-2)

To a solution of 76-1 (24.5 g, 69.9 mmol) in 250 mL dichloromethane was added the Eschenmoser's salt (16.4 g, 174.8 mmol). The mixture was refluxed over 48 hr and then cooled to room temperature. After addition of MeI (8.7 mL, 139.8 mmol) and Et_3N (24.4 mL, 174.8 mmol), the mixture was stirred at room temperature for 48 hr and concentrated. The residue was dissolved in dichloromethane (150 mL). DBU (21 mL, 139.8 mmol) was added. The mixture was stirred overnight and diluted with water (150 mL) and acidified with 6N HCl until pH=4. After removal of the solvent, the residue was extracted with EtOAc (x3). The combined organic layers were washed with brine and dried ($MgSO_4$). Concentration of the mixture afforded a yellow solid as the desired product 76-2 which was further purified by recrystalization (methanol/water).
MS calculated M-H_2O: 344.5, found 345.0.

Step C: 3-[(3S,3aS,6R)-8,8-ethylene-3-(methoxycarbonyl)-3a,6-dimethyl-7-oxododecahydro-1H-cyclopenta[a]naphthalen-6 -yl] propanoic acid (76-3)

To a suspension of trimethylsulfoxonium bromide (35.8 g, 206.9 mmol) in 180 mL DMSO was added NaH (5.0 g, 206.9 mmol) gradually (bubbles). The mixture was stirred for 1.5 hr. A solution of 76-2 (18.7 g, 51.7 mmol) in 70 mL DMSO was added rapidly via cannula and stirred for 1 hr. The mixture was poured into ice and extracted with EtOAc (x3). After removal of solvent, the residue was purified on reverse phase HPLC with gradient (5% CH_3CN/75%H_2O (0.02%)/20%MeOH) to (75% CH_3CN/5%H_2O (0.02%)/20%MeOH) over 10 min. Upon concentration, the desired product 76-3 was obtained a beige solid. MS calculated M+1: 377.5, found 377.0.

Step D: 6,6-Ethylene-5-hydroxy-3-oxo-4-aza-5α-androst-17β-carboxylic acid methyl ester (76-4)

To a solution of 76-3 (10.0 g, 26.6 mmol) in 100 mL dichloromethane at 0 ^oC was added Et_3N (14.8 mL, 106.2 mmol) and trimethylacetyl chloride (3.9 mL, 31.9 mmol) and catalytic amount of DMAP. The mixture was stirred for 1 hr. To the reaction mixture was added a solution of anhydrous ammonia in dichloromethane (prepared by bubbling anhydrous ammonia into dichloromethane for 50 min at 0 ^oC). The mixture was stirred for 2 hr at room temperature and followed by treatment with aqueous $NaHCO_3$. The organic layer was separated and dried ($MgSO_4$). Upon removal of the solvent, the desired product 76-4 was obtained as a beige solid which was used for the next step without further purification. MS calculated M+1: 376.5, found 376.1

Step E: 6,6-Ethylene-3-oxo-4-aza-5α-androst-17β-carboxylic acid methyl ester (76-5)

To a solution of 76-4 (6.4 g, 17.0 mmol) in 55 mL dichloromethane was added Et_3SiH (110 mL) and 55 mL TFA. The mixture was stirred at room temperature for 2 h and concentrated. The residue was treated with sat. $NaHCO_3$ and extracted with EtOAc (x3). The combined organic layers were washed with sat. $NaHCO_3$, brine, and dried ($MgSO_4$). After removal of the solvent, the desired product 76-5 was obtained as a colorless oil, which was used for the next step without further purification.
MS calculated M+1: 360.5, found 360.1

Step F: 6,6-Ethylene-3-oxo-4-aza-5α-androst-17β-carboxylic acid (76-6)

To a suspension of 76-5 (4.6 g, 12.8 mmol) in 80 mL methanol was added a solution of LiOH (1.6 g, 38.4 mL). The mixture was heated at 50 °C overnight. The reaction was quenched with 3N HCl until pH =3. The mixture was extracted with a mixed solvent (chloroform/isopropanol) three times. The combined organic layers were dried ($MgSO_4$). Upon removal of the solvent, the desired product, 76-6, was obtained as a beige solid, which was used in the next step without further purification.
MS calculated M+1: 346.5, found 346.0.

Step G: Ethyl -6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetate (76-7)

To a stirred solution of 6,6-ethylene-3-oxo-4-aza-5 α-androst-17β-carboxylic acid (76-6) (4.0 g, 11.6 mmol, in anhydrous CH_2Cl_2 (150.0 ml) at 0° C was added anhydrous DMF (250 µl) and thionyl chloride (1.3 ml, 17.4 mmol). After stirring at 0° C for 30 min, anhydrous toluene (50 ml) was added and removed under vacuum at ambient temperature. This was repeated to give an orange oily solid. Meanwhile, to a suspension of 1-methyl-3-nitro-1-nitrosoguanidine (8.5 g, 57.9 mmol) in diethyl ether (175 ml) at -5° C in a polypropylene Erlenmeyer flask, cold 40% aqueous KOH solution (135 ml) was added slowly. After 40 min of stirring at -5° C, the biphasic diazomethane mixture was placed in a dry ice/acetone bath until the aqueous phase was frozen (40 min). The deep yellow ether phase was filtered into a dry cold (-70° C) polypropylene Erlenmeyer flask. The frozen layer was rinsed with cold (-70° C) ether. The diazomethane solution was poured quickly into a solution of the acyl chloride in anhydrous CH_2Cl_2 (200 ml) at -5° C. After 1 h of stirring, the remaining diazomethane was removed by vigorous bubbling of nitrogen into reaction mixture. The solvent was removed under vacuum at ambient temperature to give a beige solid. This solid was dissolved in EtOH (100 ml) and the resulting solution was cooled to 0° C. Et_3N (1.9 ml, 13.9 mmol) and silver benzoate (2.7g, 11.6 mmol) were added. Vigorous bubbling occurred. The dark brown mixture was allowed to warm to ambient temperature. After 2.0 of stirring at ambient temperature, the ethanol was removed under vacuum. The residue was purified on silica gel (100% hexane to 30% EtOAc/hexane) to give the title compound as a viscous

yellow oil containing 15% 6,6-ethylene-3-oxo-4-aza-5 α-androst-17β-carboxylic acid ethyl ester. ^{1}H NMR ($CDCl_3$) δ 0.06-0.12 (m, 1H), 0.33-0.4 (m, 2H), 0.63-0.69 (m, 3H), 0.88-0.95 (m, 4H), 1.10-1.20 (m, 2H), 1.21-1.34 (m, 5H), 1.36-1.44 (m, 2H), 1.47-1.75 (m, 9H), 1.77-1.96 (m, 2H), 2.02-2.17 (m, 1H), 2.33 -2.45 (m, 2H), 3.37 (s, 1H), 4.12 (q, 2H), 5.05 (s, 1H). MS M+H: 388.0.

Step F: 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetic acid (76-8)

To a stirred solution of ethyl -6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetate (76-7)(1.2 g, 3.1 mmol) in dioxane (25 ml) and MeOH (10 ml) at 0° C was added (0.3 g, 6.2 mmol) LiOH as a solution in 20 ml water. The mixture was allowed to warm to ambient temperature. After 2 h of stirring, selective hydrolysis was complete. The mixture was diluted with 100 ml water and extracted with EtOAc. The aqueous layer was acidified to pH 3-4 with 3 N HCl. The precipitate was filtered and washed with water. The title compound was obtained as a white solid after dissolving in $CHCl_3$, drying ($MgSO_4$), and removing the solvent under vacuum. ^{1}H NMR ($CDCl_3$) δ 0.05-0.10 (m, 1H), 0.35-0.39 (m, 1H), 0.48-0.52 (m, 1H), 0.63 (s, 3H), 0.86-0.95 (m, 4H), 1.04-1.15 (m, 2H), 1.17-1.23 (m, 1H), 1.25-1.43 (m, 4H), 1.49-1.66 (m, 4H), 1.72-1.79 (m, 1H), 1.80-1.88 (m, 2H), 1.93-2.08 (m, 1H), 2.12-2.18 (m, 1H), 2.33-2.44 (m, 3H), 3.38 (s, 1H), 3.49 (s, 1H), 5.75 (s, 1H). MS M+H:360.0.

Step G: N-(5-cyclopropyl-1,3,4-thiadiazol-2-yl)-6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide (76-9)

To a stirred solution of 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetic acid (76-8) (0.05 g, 0.14 mmol) in anhydrous CH_2Cl_2 (2 ml) at 0° C was added anhydrous DMF (10.0 µl) and thionyl choride (15.0 µl, 0.2 mmol). After stirring at 0° C for 30 min, anhydrous toluene (5.0 ml) was added and removed under vacuum. This was repeated to give an orange oil which was dissolved in anhydrous CH_2Cl_2 (2.0 ml). DIPEA (0.12 ml, 0.70 mmol), DMAP (0.002 g, 0.014 mmol), and 2-amino-5-cyclopropyl-1,3,4-thiadiazole (0.06 g, 0.42 mmol) were added and mixture was heated in a microwave reactor at 120° C for 30 min. CH_2Cl_2 was removed under vacuum and the resulting brown residue was purified on reversed phase silica gel (5% CH_3CN/95% H_2O with 0.1% TFA to 80% CH_3CN/10% 95% H_2O with 0.1% TFA) to give the title compound as a beige solid. ^{1}H NMR ($CDCl_3$) δ 0.07-0.11 (m, 1H), 0.37-0.46 (m, 2H), 0.63-0.70 (m, 2H), 0.73 (s, 3H), 0.89-0.97 (m, 4H), 1.04-1.21 (m, 6H), 1.22-1.50 (m, 3H), 1.52-1.68 (m, 4H), 1.75-1.79 (m, 1H), 1.80-1.98 (m, 2H), 2.03-2.29 (m, 1H), 2.32-2.46 (m, 2H), 2.54-2.73 (m, 1H), 3.39 (s, 1H), 5.52 (s, 1H). MS calculated M+H: 483.2788, found 483.2765.

Examples 78-85 in Table 4 were prepared in a similar manner as compound (76-9), but using the appropriate amine to generate the final desired product.

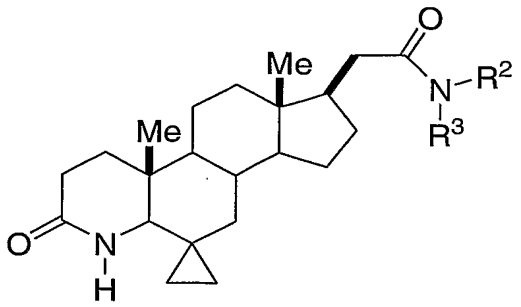
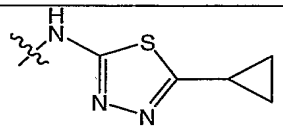
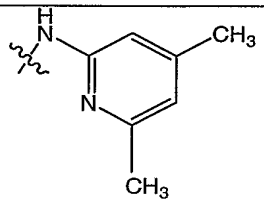
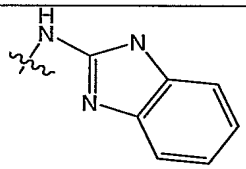
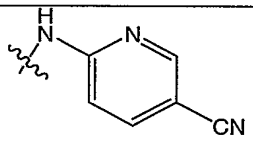
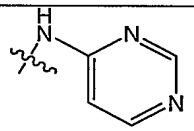
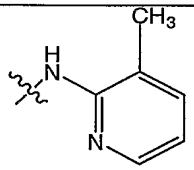
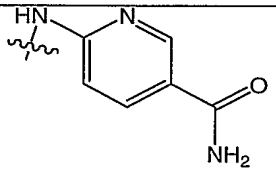
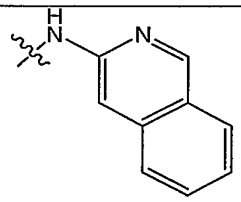
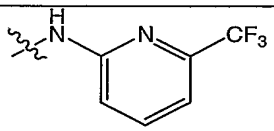
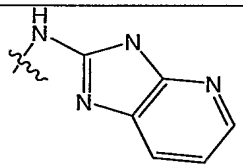
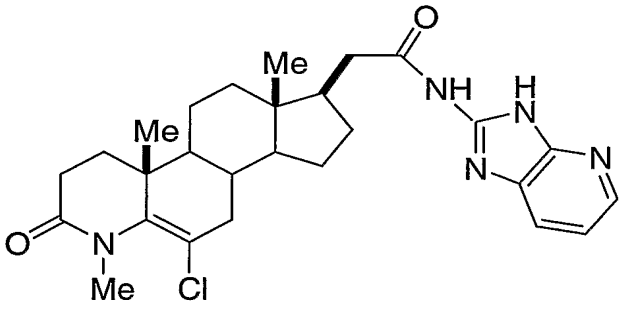


Table 4

Ex.	NR^2R^3	Name	Mass spectrum Measured [M+H]
76		*N*-[(5-cyclopropyl-1,3,4-thiadiazol-2-yl] - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	483.2765
77		*N*-[4,6-dimethyl-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	464.3233
78		*N*-(benzimidazol-2-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	475.3029
79		*N*-[5-cyano-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	461.2903
80		*N*-(1,3-pyrimid-4-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	437.2889
81		*N*-[3-methyl-pyridin-2-yl] 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	450.3132
82		*N*-[(5-carboxamido)pyrid2-l] -- 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	479.304

83		*N*-(isoquinolin-3-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	486.3155
84		*N*-[6-(trifluoromethyl)pyridin-2-yl]-6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	504.2855
85		*N*-(4-azabenzimidazol-2-yl) - 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide	476.41

Example 88



Example 88, *N*-(1H-imidazo[4,5-b] pyridin-2-yl) -4-methyl-6-chloro-3-oxo-4-aza-5α-androst-5-en-17β-acetamide, was prepared in a similar manner as compound (56-1), but using the appropriate amine. Mass spectrum measured [M+H] is 497.0

Example 89

Pharmaceutical Composition

As a specific embodiment of this invention, 100 mg of *N*-[6-(trifluoromethyl)pyridin-2-yl]- 6,6-ethylene-3-oxo-4-aza-5α-androst-17β-acetamide, is formulated with sufficient finely divided lactose to provide a total amount of 580 to 590 mg to fill a size 0, hard gelatin capsule.

While the foregoing specification teaches the principles of the present invention, with examples provided for the purpose of illustration, it is understood that the practice of the invention encompasses all of the usual variations, adoptions, or modifications, as being within the scope of the following claims and their equivalents.

ASSAYS

In Vitro and *In Vivo* Assays for SARM Activity Identification of Compounds

The compounds exemplified in the present application exhibited activity in one or more of the following assays.

Hydroxylapatite-based Radioligand Displacement Assay of Compound Affinity for Endogenously Expressed AR

Materials:

Binding Buffer: TEGM (10 mM Tris-HCl, 1 mM EDTA, 10% glycerol, 1 mM beta-mecaptoethanol, 10 mM Sodium Molybdate, pH 7.2)

50% HAP Slurry: Calbiochem Hydroxylapatite, Fast Flow, in 10 mM Tris, pH 8.0 and 1 mM EDTA.

Wash Buffer: 40 mM Tris, pH7.5, 100 mM KCl, 1 mM EDTA and 1 mM EGTA.

95% EtOH

Methyltrienolone, [17α-methyl-^{3}H], (R1881*); NEN NET590

Methyltrienolone (R1881), NEN NLP005 (dissolve in 95% EtOH)

Dihydrotestosterone (DHT) [1,2,4,5,6,7-^{3}H(N)] NEN NET453

Hydroxylapatite Fast Flow; Calbiochem Cat#391947

Molybdate = Molybdic Acid (Sigma, M1651)

MDA-MB-453 cell culture media:

RPMI 1640 (Gibco 11835-055) w/23.8 mM $NaHCO_3$, 2 mM L-glutamine

in 500 mL of complete media	Final conc.
10 mL (1M Hepes)	20 mM
5 mL (200 mM L-glu)	4 mM
0.5 mL (10 mg/mL human insulin) in 0.01 N HCl Calbiochem#407694-S)	10 μg/mL
50 mL FBS (Sigma F2442)	10%

1 mL (10 mg/mL Gentamicin Gibco#15710-072)	20 μg /mL

Cell Passaging

Cells (Hall R. E., et al., European Journal of Cancer, 30A: 484-490 (1994)) are rinsed twice in PBS, phenol red-free Trypsin-EDTA is diluted in the same PBS 1:10. The cell layers are rinsed with 1X Trypsin, extra Trypsin is poured out, and the cell layers are incubated at 37°C for ~ 2 min. The flask is tapped and checked for signs of cell detachment. Once the cells begin to slide off the flask, the complete media is added to kill the trypsin. The cells are counted at this point, then diluted to the appropriate concentration and split into flasks or dishes for further culturing (Usually 1:3 to 1:6 dilution).

Preparation of MDA-MB-453 Cell Lysate

When the MDA cells are 70 to 85% confluent, they are detached as described above, and collected by centrifuging at 1000 g for 10 minutes at 4°C. The cell pellet is washed twice with TEGM (10 mM Tris-HCl, 1 mM EDTA, 10% glycerol, 1 mM beta-mercaptoethanol, 10 mM Sodium Molybdate, pH 7.2). After the final wash, the cells are resuspended in TEGM at a concentration of 10^7 cells/mL. The cell suspension is snap frozen in liquid nitrogen or ethanol/dry ice bath and transferred to –80°C freezer on dry ice. Before setting up the binding assay, the frozen samples are left on ice-water to just thaw (~1 hr). Then the samples are centrifuged at 12,500 g to 20,000 g for 30 min at 4°C. The supernatant is used to set-up assay right away. If using 50 μL of supernatant, the test compound can be prepared in 50 μL of the TEGM buffer.

Procedure for Multiple Compound Screening

1x TEGM buffer is prepared, and the isotope-containing assay mixture is prepared in the following order: EtOH (2% final concentration in reaction), ^{3}H-R1881 or ^{3}H-DHT (0.5 nM final Conc. in reaction) and 1x TEGM. [eg. For 100 samples, 200 μL (100 x 2) of EtOH + 4.25 μL of 1:10 ^{3}H-R1881 stock + 2300 μL (100 x 23) 1x TEGM]. The compound is serially diluted, e.g., if starting final conc. is 1 μM, and the compound is in 25 μL of solution, for duplicate samples, 75 μL of 4x1 μM solution is made and 3 μL of 100 μM is added to 72 μL of buffer, and 1:5 serial dilution.

25μL of ^{3}H-R1881 trace and 25 μL compound solution are first mixed together, followed by addition of 50 μL receptor solution. The reaction is gently mixed, spun briefly at about 200 rpm and incubated at 4°C overnight. 100 μL of 50% HAP slurry is prepared and added to the incubated reaction which is then vortexed and incubated on ice for 5 to 10 minutes. The reaction mixture is vortexed twice more to resuspend HAP while incubating reaction. The samples in 96-well format are

then washed in wash buffer using The FilterMate™ Universal Harvester plate washer (Packard). The washing process transfers HAP pellet containing ligand-bound expressed receptor to Unifilter-96 GF/B filter plate (Packard). The HAP pellet on the filter plate is incubated with 50 μL of MICROSCINT (Packard) scintillint for 30 minutes before being counted on the TopCount microscintillation counter (Packard). IC_{50}s are calculated using R1881 as a reference.

The compounds, Examples 1-34, found in Tables 1-4, and Examples 35 and 36 were tested in the above assay and found to have an IC_{50} value of 1 micromolar or less.

MMP1 Promoter Suppression, Transient Transfection Assay (TRAMPS)

HepG2 cells are cultured in phenol red free MEM containing 10 % charcoal-treated FCS at 37°C with 5% CO_2. For transfection, cells are plated at 10,000 cells/well in 96 well white, clear bottom plates. Twenty four hours later, cells are co-transfected with a MMP1 promoter-luciferase reporter construct and a rhesus monkey expression construct (50 : 1 ratio) using FuGENE6 transfection reagent, following the protocol recommended by manufacturer. The MMP1 promoter-luciferase reporter construct is generated by insertion of a human MMP1 promoter fragment (-179/+63) into pGL2 luciferase reporter construct (Promega) and a rhesus monkey AR expression construct is generated in a CMV-Tag2B expression vector (Stratagene). Cells are further cultured for 24 hours and then treated with test compounds in the presence of 100 nM phorbol-12-myristate-13-acetate (PMA), used to increase the basal activity of MMP1 promoter. The compounds are added at this point, at a range of 1000nM to 0.03nM, 10 dilutions, at a concentration on 10X, 1/10th volume (example:10 microliters of ligand at 10X added to 100 microliters of media already in the well). Cells are further cultured for an additional 48 hours. Cells are then washed twice with PBS and lysed by adding 70 μL of Lysis Buffer (1x, Promega) to the wells. The luciferase activity is measured in a 96-well format using a 1450 Microbeta Jet (Perkin Elmer) luminometer. Activity of test compounds is presented as suppression of luciferase signal from the PMA-stimulated control levels. EC_{50} and Emax values are reported. SARMs of the present invention activate repression typically with submicromolar EC_{50} values and Emax values greater than about 50%.

See Newberry EP, Willis D, Latifi T, Boudreaux JM, Towler DA, "Fibroblast growth factor receptor signaling activates the human interstitial collagenase promoter via the bipartite Ets-AP1 element," Mol. Endocrinol.11: 1129-44 (1997) and Schneikert J, Peterziel H, Defossez PA, Klocker H, Launoit Y, Cato AC, "Androgen receptor-Ets protein interaction is a novel mechanism for steroid hormone-mediated down-modulation of matrix metalloproteinase expression," J. Biol. Chem. 271: 23907-23913 (1996).

Mammalian Two-Hybrid Assay for the Ligand-induced Interaction of N-Terminus and C-Terminus Domains of the Androgen Receptor (Agonist Mode)

This assay assesses the ability of AR agonists to induce the interaction between the N-terminal domain (NTD) and C-terminal domain (CTD) of rhAR that reflects the *in vivo* virilizing potential mediated by activated androgen receptors. The interaction of NTD and CTD of rhAR is quantified as ligand induced association between a Gal4DBD-rhARCTD fusion protein and a VP16-rhARNTD fusion protein as a mammalian two-hybrid assay in CV-1 monkey kidney cells.

The day before transfection, CV-1 cells are trypsinized and counted, and then plated at 20,000 cells/well in 96-well plates or larger plates (scaled up accordingly) in DMEM + 10% FCS. The next morning, CV-1 cells are cotransfected with pCBB1 (Gal4DBD-rhARLBD fusion construct expressed under the SV40 early promoter), pCBB2 (VP16 -rhAR NTD fusion construct expressed under the SV40 early promoter) and pFR (Gal4 responsive luciferase reporter, Promega) using LIPOFECTAMINE PLUS reagent (GIBCO-BRL) following the procedure recommended by the vendor. Briefly, DNA admixture of 0.05 μg pCBB1, 0.05 μg pCBB2 and 0.1 μg of pFR is mixed in 3.4 μL OPTI-MEM (GIBCO-BRL) mixed with "PLUS Reagent" (1.6 μL, GIBCO-BRL) and incubated at room temperature (RT) for 15 min to form the pre-complexed DNA.

For each well, 0.4 μL LIPOFECTAMINE Reagent (GIBCO-BRL) is diluted into 4.6 μL OPTI-MEM in a second tube and mixed to form the diluted LIPOFECTAMINE Reagent. The pre-complexed DNA (above) and the diluted LIPOFECTAMINE Reagent (above) are combined, mixed and incubated for 15 minutes at room temperature. The medium on the cells is replaced with 40 μL /well OPTI-MEM, and 10 μL DNA-lipid complexes are added to each well. The complexes are mixed into the medium gently and incubated at 37°C at 5% CO_2 for 5 hours. Following incubation, 200 μL /well D-MEM and 13% charcoal-stripped FCS are added, followed by incubation at 37°C at 5% CO_2. After 24 hours, the test compounds are added at the desired concentration(s) (1 nM – 10 μM). Forty eight hours later, luciferase activity is measured using LUC-Screen system (TROPIX) following the manufacturer's protocol. The assay is conducted directly in the wells by sequential addition of 50 μL each of assay solution 1 followed by assay solution 2. After incubation for 40 minutes at room temperature, luminescence is directly measured with 2-5 second integration.

Activity of test compounds is calculated as the E_{max} relative to the activity obtained with 3 nM R1881. Typical tissue-selective androgen receptor modulators of the present invention display weak or no agonist activity in this assay with less than 50% agonist activity at 10 micromolar.

See He B, Kemppainen JA, Voegel JJ, Gronemeyer H, Wilson EM, "Activation function in the human androgen receptor ligand binding domain mediates inter-domain communication with the NH(2)-terminal domain," J. Biol. Chem. 274: 37219-37225 (1999).

A Mammalian Two-Hybrid Assay For Inhibition of Interaction between N-Terminus and C-Terminus Domains of Androgen Receptor (Antagonist Mode)

This assay assesses the ability of test compounds to antagonize the stimulatory effects of R1881 on the interaction between NTD and CTD of rhAR in a mammalian two-hybrid assay in CV-1 cells as described above.

Forty eight hours after transfection, CV-1 cells are treated with test compounds, typically at 10 μM, 3.3 μM, 1 μM, 0.33 μM, 100 nM, 33 nM, 10 nM, 3.3 nM and 1 nM final concentrations. After incubation at 37°C at 5% CO_2 for 10-30 minutes, an AR agonist methyltrienolone (R1881) is added to a final concentration of 0.3 nM and incubated at 37°C. Forty-eight hours later, luciferase activity is measured using LUC-Screen system (TROPIX) following the protocol recommended by the manufacturer. The ability of test compounds to antagonize the action of R1881 is calculated as the relative luminescence compared to the value with 0.3 nM R1881 alone.

Trans-Activation Modulation of Androgen Receptor (TAMAR)

This assay assesses the ability of test compounds to control transcription from the MMTV-LUC reporter gene in MDA-MB-453 cells, a human breast cancer cell line that naturally expresses the human AR. The assay measures induction of a modified MMTV LTR/promoter linked to the LUC reporter gene.

20,000 to 30,000 cells/well are plated in a white, clear-bottom 96-well plate in "Exponential Growth Medium" which consists of phenol red-free RPMI 1640 containing 10%FBS, 4mM L-glutamine, 20mM HEPES, 10ug/mL human insulin, and 20ug/mL gentamicin. Incubator conditions are 37°C and 5% CO_2. The transfection is done in batch mode. The cells are trypsinized and counted to the right cell number in the proper amount of fresh media, and then gently mixed with the Fugene/DNA cocktail mix and plated onto the 96-well plate. All the wells receive 200 Tl of medium + lipid/DNA complex and are then incubated at 37°C overnight. The transfection cocktail consists of serum-free Optimem, Fugene6 reagent and DNA. The manufacturer's (Roche Biochemical) protocol for cocktail setup is followed. The lipid (Tl) to DNA (Tg) ratio is approximately 3:2 and the incubation time is 20 minutes at room temperature. Sixteen to 24 hrs after transfection, the cells are treated with test compounds such that the final DMSO (vehicle) concentration is <3%. The cells are exposed to the test

compounds for 48 hours. After 48 hours, the cells are lysed by a Promega cell culture lysis buffer for 30-60 minutes and then the luciferase activity in the extracts is assayed in the 96-well format luminometer.

Activity of test compounds is calculated as the E_{max} relative to the activity obtained with 100 nM R1881.

See R.E. Hall, et al., "MDA-MB-453, an androgen-responsive human breast carcinoma cell line with high androgen receptor expression," Eur. J. Cancer, 30A: 484-490 (1994) and R.E. Hall, et al., "Regulation of androgen receptor gene expression by steroids and retinoic acid in human breast-cancer cells," Int. J. Cancer., 52: 778-784 (1992).

In Vivo Prostate Assay

Male Sprague-Dawley rats aged 9-10 weeks, the earliest age of sexual maturity, are used in prevention mode. The goal is to measure the degree to which androgen-like compounds delay the rapid deterioration (~-85%) of the ventral prostate gland and seminal vesicles that occurs during a seven day period after removal of the testes (orchiectomy [ORX]).

Rats are orchiectomized (ORX). Each rat is weighed, then anesthetized by isoflurane gas that is maintained to effect. A 1.5 cm anteroposterior incision is made in the scrotum. The right testicle is exteriorized. The spermatic artery and vas deferens are ligated with 4.0 silk 0.5cm proximal to the testicle. The testicle is freed by one cut of a small surgical scissors distal to the ligation site. The tissue stump is returned to the scrotum. The same is repeated for the left testicle. When both stumps are returned to the scrotum, the scrotum and overlying skin are sutured closed with 4.0 silk. For Sham-ORX, all procedures excepting ligation and scissors cutting are completed. The rats fully recover consciousness and full mobility within 10-15 minutes.

A dose of test compound is administered subcutaneously or orally to the rat immediately after the surgical incision is sutured. Treatment continues for an additional six consecutive days.

Necropsy and Endpoints

The rat is first weighed, then anesthetized in a CO_2 chamber until near death. Approximately 5ml whole blood is obtained by cardiac puncture. The rat is then examined for certain signs of death and completeness of ORX. Next, the ventral portion of the prostate gland is located and blunt dissected free in a highly stylized fashion. The ventral prostate is blotted dry for 3-5 seconds and then weighed (VPW). Finally, the seminal vesicle is located and dissected free. The ventral seminal vesicle is blotted dry for 3-5 seconds and then weighed (SVWT).

Primary data for this assay are the weights of the ventral prostate and seminal vesicle. Secondary data include serum LH (luteinizing hormone) and FSH (follicle stimulating hormone), and

possible serum markers of bone formation and virilization. Data are analyzed by ANOVA plus Fisher PLSD post-hoc test to identify intergroup differences. The extent to which test compounds inhibit ORX-induced loss of VPW and SVWT is assessed.

In Vivo Bone Formation Assay:

Female Sprague-Dawley rats aged 7-10 months are used in treatment mode to simulate adult human females. The rats have been ovariectomized (OVX) 75-180 days previously, to cause bone loss and simulate estrogen deficient, osteopenic adult human females. Pre-treatment with a low dose of a powerful anti-resorptive, alendronate (0.0028mpk SC, 2X/wk) is begun on Day 0. On Day 15, treatment with test compound is started. Test compound treatment occurs on Days 15-31 with necropsy on Day 32. The goal is to measure the extent to which androgen-like compounds increase the amount of bone formation, shown by increased fluorochrome labeling, at the periosteal surface.

In a typical assay, nine groups of seven rats each are studied.

On Days 19 and 29 (fifth and fifteenth days of treatment), a single subcutaneous injection of calcein (8mg/kg) is given to each rat.

Necropsy and Endpoints

The rat is first weighed, then anesthetized in a CO_2 chamber until near death. Approximately 5mL whole blood is obtained by cardiac puncture. The rat is then examined for certain signs of death and completeness of OVX. First, the uterus is located, blunt dissected free in a highly stylized fashion, blotted dry for 3-5 seconds and then weighed (UW). The uterus is placed in 10% neutral-buffered formalin. Next, the right leg is disarticulated at the hip. The femur and tibia are separated at the knee, substantially defleshed, and then placed in 70% ethanol.

A 1-cm segment of the central right femur, with the femoral proximal-distal midpoint ats center, is placed in a scintillation vial and dehydrated and defatted in graded alcohols and acetone, then introduced to solutions with increasing concentrations of methyl methacrylate. It is embedded in a mixture of 90% methyl methacrylate: 10% dibutyl phthalate that is allowed to polymerize over a 48-72 hours period. The bottle is cracked and the plastic block is trimmed into a shape that conveniently fits the vice-like specimen holder of a Leica 1600 Saw Microtome, with the long axis of the bone prepared for cross-sectioning. Three cross-sections of 85μm thickness are prepared and mounted on glass slides. One section from each rat that approximates the midpoint of the bone is selected and blind-coded. The periosteal surface of each section is assessed for total periosteal surface, single fluorochrome label, double fluorochrome label, and interlabel distance.

Primary data for this assay are the percentage of periosteal surface bearing double label and the mineral apposition rate (interlabel distance(μm)/10d), semi-independent markers of bone formation. Secondary data include uterus weight and histologic features. Tertiary endpoints can include serum markers of bone formation and virilization. Data are analyzed by ANOVA plus Fisher PLSD post-hoc test to identify intergroup differences. The extent to which test compounds increase bone formation endpoint are assessed.